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THE ARMY TECHNOLOGY BASE:
ISSUES AND COMPARISONS

by

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The Army Technology Base:
Issues and Comparisons

by

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Lieutenant, United States Navy
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ABSTRACT

This thesis compares the Army, Navy, and Air Force technology base programs for the purpose of identifying features of the Navy and Air Force programs that might benefit the Army. This study also examines three technology base issues to assess how well the Army's program responds to their concerns. As a result of these efforts, four recommendations are proposed to improve the Army's technology base resource allocation process.

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LIST OF ACRONYMS

AFOSR	Air Force Office of Scientific Research
AMC	Army Materiel Command
ARO	Army Research Office
ASAF(A)	Assistant Secretary of the Air Force for Acquisition
ASW	Anti-submarine Warfare
ATD	Advanced Technology Demonstration
BDP	Battlefield Development Plan
CBRS	Concepts Based Requirements System
CMC	Commandant of the Marine Corps
CNO	Chief of Naval Operations
COE	Corps of Engineers
DARPA	Defense Advanced Research Projects Agency
DCS T&P	Deputy Chief of Staff for Technology and Plans
DCSPER	Deputy Chief of Staff for Personnel
DDR&E	Director of Defense Research and Engineering
DOD	Department of Defense
DON	Department of the Navy
DRS	Defense Research Sciences
DS&T	Director of Science and Technology
DSB	Defense Science Board
DT&A	Deputy for Technology and Assessment
DUSD	Deputy Under Secretary of Defense

HQ	Headquarters
IED	Independent Exploratory Development
ILIR	In-House Laboratory Independent Research
LABCOM	Laborato.·· Command
MAA	Mission Area Analysis
MAM	Mission Area Manager
MAMP	Mission Area Material Plan
OAT	Office of Advanced Technology
OCNR	Office of Chief of Naval Research
ONR	Office of Naval Research
ONT	Office of Naval Technology
OSD	Office of Secretary of Defense
PE	Program Element
POM	Program Objectives Memorandum
R&AT	Research and Advanced Technology
R&D	Research and Development
RDT&E	Research, Development, Test and Evaluation
S&T	Science and Technology
SDI	Strategic Defense Initiative
SDIO	Strategic Defense Initiative Organization
TRADOC	Training and Doctrine Command
TSG	The Surgeon General
UAV	Unmanned Airborne Vehicle
URI	University Research Initiative
USD(A)	Under Secretary of Defense for Acquisition

I. INTRODUCTION

A. BACKGROUND

For the last four decades the United States and its allies have developed national security policies predicated upon a credible nuclear and non-nuclear deterrence of the Warsaw Pact. These have been based on the realization that only through qualitative superiority would we be able to deter or defeat the numerically superior threat. During World War II, this country developed a unique process capable of providing its troops with the best equipment that could be made available. The process was and is predicated upon the availability of innovative basic research that is applied to the development of sophisticated fielded weapons systems. However, many in Congress and within the science and technology (S&T) community feel that we are losing our capability to ensure the availability of technology innovations to draw upon. One recent report states that:

> ...Over the last twenty years, we have seen a gradual weakening of this process. Imperceptible at first and so gradual that the seriousness of the change is only barely apparent now... We are seeing a steady erosion of the commitment to qualitative superiority. [Ref. 1:p. 1]

As an indication of the severity of the situation, the Deputy Secretary of Defense is currently conducting two studies. One is to identify ways to consolidate or restructure the Department of Defense (DOD) laboratories and

research centers, and the other is to identify ways to similarly restructure the test and evaluation facilities [Ref. 2:p. 4]. This is no small undertaking as the Pentagon spends about $7.9 billion a year on a network of approximately 72 laboratories and research centers. An additional $7.9 billion is spent on military ranges and test facilities. [Ref. 3:p. 1]

DOD identifies those research efforts which lead to the development of specific military capabilities as its technology base program. The technology base can be viewed as the front-end investment in the acquisition process and encompasses work prior to a deployment decision [Ref. 1:p. 17]. The technology base is further subdivided into three activities: basic research (category 6.1), exploratory development (category 6.2), and advanced exploratory development (category 6.3).[1] The technology base is often obscured by the larger funding category, Research, Development, Test and Evaluation (RDT&E), of which it is part.

For instance, during the Carter-Reagan defense buildup, RDT&E funding increased nearly 100 percent. Many mistakenly believe that the technology base portion of RDT&E enjoyed a

---

[1] DOD budget categories for research, exploratory development, and advanced exploratory development are 6.1, 6.2, and 6.3 respectively. These terms are used interchangeably throughout this thesis.

commensurate resource infusion. This is not so. When one discounts Strategic Defense Initiative (SDI) funding, science and technology (S&T) activity levels have remained essentially unchanged for the past twenty years. The technology base clearly did not benefit from the expansion that the other RDT&E elements experienced in the late 1970's and early 1980's.[Ref. 4:pp. 34-35]

The deteriorating state of our technology base extends beyond the issue of inadequate funding. In recent years, numerous studies and reports have been generated on this issue. No unanimous conclusions or prescriptive solutions have been forthcoming. However, the researchers are in agreement that the topic is worthy of continued investigation.

B. OBJECTIVES OF THE STUDY

This project was initiated when the Chief of the Concepts and Analysis Branch in the Army's Laboratory Command (LABCOM) expressed interest in how funds are allocated to the various technology base programs. This interest lay in questions such as these: How many resources should be devoted to research vice exploratory development or advanced exploratory development? From an even larger perspective, what portion of the Army's RDT&E budget should be allocated to the technology base? In fact, should this funding represent a

fixed percentage, a total dollar amount, or should it vary from year to year on the basis of some discrete determinants?

Such questions, however important, are beyond the scope of this thesis. Instead, the central issue of this research is to determine how the other services manage their technology base investments. For instance, do they attempt to fund their S&T efforts at a predetermined level? How do they prioritize resource distribution among the three elements of the technology base? How does their management organization differ from the Army's? Essentially, this research examines Navy and Air Force technology base programs for features that could benefit the Army while also identifying technology base issues of importance to influential groups external to the Army - Congress, OSD, the Administration, and industry. The goal is that these issues, once identified, can be acted upon to enhance the success and effectiveness of the Army's technology base strategy.

The Army has developed a technology base strategy for the distribution of its technology base resources. This strategy proposes that 50 percent of the technology base be allocated to the development of next-generation and future systems. Twenty-five percent is targeted at developing emerging technologies. Fifteen percent is earmarked for systemic or chronic problems and ten percent is reserved for maintenance of the technology base infrastructure. When interviewed, numerous LABCOM personnel indicated a belief that this

distribution of technology base funds evolved over time and, when the Army promulgated its technology base investment strategy, this practice was endorsed because it conveniently explained what the Army had been doing. Furthermore, it was anticipated that the Army would continue to fund its technology base in roughly these same proportions.

This strategy is not necessarily incorrect or inadequate. It may have evolved precisely because it distributes resources optimally to the various elements of the technology base. The primary objective of this thesis is to compare the Army's technology base program, management structure, and resource allocation practices with those of the Navy and the Air Force. A second objective of this thesis is to identify three pervasive concerns expressed by major stakeholders such as Congress, the Administration, and those within the DOD S&T community. While many concerns about the technology base are pervasive, not all are relevant to this thesis. Moreover, there is not time to discuss all of them.

Selection criteria were developed to determine which issues should be examined. It was determined that the issues should be pervasive, relate to the basic issue of technology base resource allocation, and reflect concerns over which the Army could independently exercise a considerable degree of control. The following three issues meet these criteria and will be examined in this study:

- The trend of decreased funding for technology base programs. This trend underscores the belief that we are compromising future capabilities for present systems acquisitions.

- The perception that technology base managers are risk averse.

- The debate on the best way to ensure continued technical innovation. Should the selection process emphasize objectives to be attained (requirements pull) or should basic research and exploratory development be conducted without objective in the realization that some breakthroughs will inevitably occur (technology push)?

The purpose is to examine these concerns and relate them to the Army's technology base program and investment strategy. Recommendations on possible courses of action to address these issues will be proposed.

C. RESEARCH QUESTIONS

Research questions were developed to facilitate specific recommendations to improve the effectiveness of the Army's management of its technology base. The research questions are as follows:

- How does the Army's management of its technology base compare with those of the Navy and Air Force in terms of...

  - its management structure?

  - its relative priority for funding 6.1, 6.2, and 6.3A programs?

  - the philosophy of its investment strategy?

- Can the Army benefit from the adoption of certain features of the other services' technology base investment strategies?

- How well does the Army's technology base management and investment strategy address the pervasive issues

identified? More specifically, what can the Army do to overcome deficiencies posed by these issues?

D. RESEARCH METHODOLOGY

The research method involved examination of the technology base programs conducted by the Army, the Navy, and the Air Force. Emphasis was placed upon their management structures, prioritization of the budget categories within the programs, and philosophies of their investment strategies. Data on the services' programs was obtained through an extensive literature review and interviews with individuals in the Army's LABCOMM and the Navy's Office of Naval Research (ONR) and Office of Naval Technology (ONT).

The research method also involved an extensive literature review of current and recent studies pertinent to DOD's technology base program. These were invaluable in selecting, identifying and researching the three issues, mentioned previously, which will be discussed in this thesis. These issues are:

- The trend of decreased funding for technology base programs.
- The perception that technology base managers are risk averse.
- The debate on the best way to ensure continued technical innovation.

E. SCOPE AND ASSUMPTIONS

The scope of this thesis is limited to issues about the allocation of resources to and within the technology base.

The scope is further limited to those issues over which the Army can independently exercise control. For instance, there is considerable concern within Congress and the S&T community that DOD's technology base management organization lacks the capability to coordinate the activities of the various S&T performers (i.e., the Services, DARPA, etc.)

Most of the available studies and literature generalize about the technology base from an overall DOD or national perspective. They do not specifically address the Army's conduct or management of its technology base. Yet, because the services autonomously pursue their own technology base objectives with independent organizations for the execution and management of these pursuits, the assumption has been made that the three chosen issues have distinctive implications for each of these organizations as well. Criteria for selection of the issues examined in this thesis were chosen in part to ensure that this assumption was valid.

F. ORGANIZATION OF STUDY

This thesis is composed of five chapters. The first chapter has provided an introduction. The second chapter provides background information about the technology base in general and how program guidance is developed and promulgated at the OSD level. Information in this chapter is essential to an understanding of later chapters. The third chapter examines how the three services conduct their S&T programs.

Comparisons are made between the Army's program and those of the Navy and Air Force. The fourth chapter discusses three issues relevant to the Army's technology base. The fifth chapter provides conclusions and recommendations resulting from this research.

II. DEPARTMENT OF DEFENSE

A. GENERAL

This chapter provides background information on the process, structure, and strategy of DOD's S&T program. This information is essential to an understanding of material in the following chapters. Included in this chapter are an overview and discussion of the following:

- Funding categories within DOD's RDT&E program.
- Composition of the programs that comprise each of the S&T budget categories.
- DOD S&T oversight and management organization.
- DOD technology base investment strategy.
- Agencies that contribute to the management and implementation of DOD's S&T effort.

B. BUDGET CATEGORIES

Within DOD, funding for all Research, Development, Test, and Evaluation (RDT&E) is reported in six budget subcategories. These categories are numbered from 6.1 to 6.6. The definitions of these categories follow:

6.1 Research - Includes scientific study and experimentation directed toward increasing knowledge and understanding in those fields of the physical, engineering, environmental, biological, medical, and behavioral-social sciences related to long-term national security needs. It provides fundamental knowledge for the solution of military problems. It also provides part of the base for subsequent exploratory and advanced development in defense related technologies and of new or improved military functional capabilities in various scientific fields.

6.2 Exploratory Development - Includes all the efforts directed towards the solution of specific military problems, short of major development projects. This type of effort may vary from fairly fundamental applied research to quite sophisticated breadboard hardware[2], study programming efforts.

6.3 Advanced Development - Includes all projects which have moved into the development of hardware for experimental or operational test. It is characterized by line item projects, and program control is exercised on a project basis. The focus of Advanced Exploratory Development (6.3A) lies in the design of items being directed toward hardware for testing of operational feasibility, as opposed to items designed and engineered for eventual Service use.

6.4 Engineering Development - Includes all those development programs being engineered for Service use but which have not yet been approved for procurement or operation.

6.5 Management Support - Includes research and development effort directed toward support of installations or operations required for general research and development use. Included would be test ranges, military construction, maintenance support of laboratories, operations and maintenance of test aircraft and ships, and studies and analysis in support of the R&D program. Cost of the laboratory personnel, either in-house or contract-operated, would be assigned to appropriate projects or as line items in the Research Exploratory Development, or Advanced Development Program areas, as appropriate. Military construction costs directly related to a major development program will be included in the appropriate element.

6.6 Operational Systems Development - Includes research and development effort directed toward development, engineering, and test of systems, support programs, vehicles and weapons that have been approved for production and Service employment. 6.6 is not an official category as are 6.1-6.5, but is a term used for convenience in reference and discussion. Thus, no program element will exist numbered 6.6. [Ref. 5:pp. 2-7]

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[2] Breadboard hardware is a term used to identify an experimental model or a prototype.

DOD has historically defined its S&T program as consisting of funding categories 6.1, 6.2, and 6.3A. However, the technology base was defined as consisting of categories 6.1 and 6.2 only. In recent years, these definitions have been used interchangeably. Throughout this thesis, the two terms are used interchangeably and include the 6.3A category.

C. DEPARTMENT OF DEFENSE TECHNOLOGY BASE PROGRAM

1. Research (6.1)

The Armed Forces have supported research since the early days of the nation. For example, the Army funded the Lewis and Clark expedition in 1804. Before the National Science Foundation and the National Aeronautics and Science Administration, DOD supported most of the nation's basic research. In the 1950's and early 1960's, DOD supported about 80 percent of the federally funded research. Today, DOD supports about 66 percent of the federal research, but only 13 percent of the basic research. [Ref. 4:pp. 55-56]

In FY89, DOD spent approximately $956 million on research. As Table 1 indicates, the Navy was the largest single contributor at $352 million. The Army and Air Force supported $171 million and $197 million respectively. DARPA and the Defense Agencies sponsored the remaining $236 million basic research effort. [Ref. 6:p. 15]

The Pentagon views basic research as a crucial source of future technology. Unlike other programs, research is not necessarily expected to result in a military application.

> It is just as important to identify and terminate the failures (and perhaps learn from those lessons) as it is to recognize and expedite the successes. [Ref. 7:p. 8]

Thus, research is selected on its scientific merit and its potential for future application to the DOD mission. Lewis contends that it is sometimes necessary to force technologies

TABLE 1. DOD FY89 FUNDING OF TECHNOLOGY BASE PROGRAMS (millions $)

	Army	Navy	Air Force	DARPA	Defense Agencies	Total
Research (6.1)	$171	$352	$197	$88	$148	$956
Exploratory Development (6.2)	$571	$430	$588	$624	$309	$2522
Advanced Technology Development (6.3A)	$415	$190	$758	$557	$179	$2099
Total Services and Defense Agencies	$1157	$972	$1543	$1269	$636	$5577
Strategic Defense Initiative Organization						$3606
Total DOD Technology Base Programs						$9183

Source: Compiled from data provided by the Office of the CNO and from *Planning, Managing, and Funding DOD's Technology Base Programs*, Davey, Michael E., May 1989.

"even if we conclude that the pursuit of a given technology will pay no dividends...so that we can assess the military implications of that technology should the enemy choose to exploit it." [Ref. 8:p. 1]

DOD supports research initiatives in such diverse fields of science as these: [Ref. 4:p. 56]

- physics
- astronomy
- electronics
- mathematics
- materials
- oceanography
- chemistry
- astrophysics
- behavioral sciences
- radiation sciences
- terrestrial sciences
- atmospheric sciences
- computer science
- energy conversion
- aeronautical sciences
- medical and biological sciences

Research (6.1) is composed of three program elements (PE's). They are the Defense Research Sciences (DRS), the University Research Initiative (URI), and In-House Laboratory Independent Research (ILIR).

DRS is the largest PE with funding approaching $800 million. Universities receive about half of the DRS funds via a competitive process. Primary emphasis of the university research is on single investigator efforts, in which a single professor is assisted by a small group of postdoctoral scholars and graduate students. DRS efforts generally focus on a single scientific discipline and the average award is about $100 thousand, a figure that varies

from discipline to discipline. DRS supports about 4000 scholars in 285 institutions in all 50 states and the District of Columbia. Projects are funded from three to five years, with approximately 1000 projects awarded each year. [Ref. 9:pp. 4-5]

The URI PE also supports university research. However, the emphasis of the URI program is on research conducted by multidisciplinary teams. About 85 percent of URI funds support research conducted by multidisciplinary teams. The remainder supports graduate fellowship programs and faculty development programs. About 1000 graduate students participate. The URI projects are funded for three years. [Ref. 9:pp. 7-11]

URI and DRS projects are selected on the basis of merit competition. Each year, the Services and the Defense agencies advertise through the Commerce Business Daily and in brochures put out by each of the agencies, called Broad Agency Announcements, or BAA's. Proposals are evaluated on the basis of scientific or technical merit and the potential relevance to the DOD mission. The relevance requirement is statutory and is a consequence of the Mansfield Amendment, enacted in 1970. [Ref. 9:pp. 11-12]

The third PE within the 6.1 category is ILIR. The Navy actually has two types of ILIR. One is Independent Research and it is a 6.1 PE. The other is Independent

Exploratory Development (IED) and it is a function of the 6.2 budget category. [Ref. 10:p. 3]

ILIR provides flexibility to the Laboratory Directors. ILIR projects are conducted in the service labs and do not require pre-approval like most other research endeavors. Instead, reports on the ILIR fund usage is provided at the end of the year. All the services supported ILIR in FY90 and in the FY91 budget requests.

> Besides being their main source of discretionary funds, ILIR helps maintain an atmosphere of creativity and research excellence, provides seed money which can lead to new research efforts, which enhance the labs' S&T bases, and most importantly assists the laboratory directors in hiring new researchers ... The Defense Science Board stated that "A successful laboratory requires discretionary basic research funding for its long-term vitality." The DSB recommended that at least five percent and up to ten percent of the annual funding of Federal Laboratories should consist of ILIR funds. [Ref. 6:p. 30]

DRS accounts for approximately 90 percent of the 6.1 budget. ILIR supports about 6 percent of DOD's research budget and the remaining 4 percent is devoted to the URI programs. [Ref. 4:p. 57]

2. Exploratory Development (6.2)

Basic research (6.1) that shows promise and potential for military application is advanced to exploratory development. Exploratory development encompasses all efforts, short of major development, directed toward the solution of specific military problems. These efforts vary from fundamental applied research to development of sophisticated breadboard hardware.

This category of research is composed of multiple PE's, with each service's programs composed of a unique set of PE's. For instance, the Navy has 14 PE's keyed to Naval warfare mission areas. [Ref. 11:p. 19]

3. Advanced Technology Development (6.3A)

Advanced technology development, or advanced exploratory development, is intended to assist the services in transferring the most promising new technologies into weapons systems in a timely manner. DOD's 6.3A program attempts to facilitate this transfer by funding the building and testing of "breadboard" prototypes that, while inexpensive and quickly assembled, still provide adequate assessment and feasibility of the military application of a new technology. Prototyping of this sort has two inherent benefits.

- It speeds introduction of new technology into fielded systems.
- It provides better information on likely cost performance and development schedules, allowing for better decisions on which weapons should enter full-scale development. [Ref. 12:p. 22]

D. THE DOD TECHNOLOGY BASE ORGANIZATION

1. Military Reform Act of 1986

The Military Reform Act of 1986, often referred to as the Goldwater-Nichols Act, abolished the Office of the Undersecretary of Defense for Research and Engineering and replaced it with the Under Secretary of Defense for

Acquisition (USD(A)). It also recreated the Office of the Director of Defense Research and Engineering (DDR&E).

The purpose of this act was to provide a separation of those responsible for research and development from those responsible for production decisions. The intention was to ensure that weapons transferred from the laboratory to the factory had attained an acceptable level of technological maturity. [Ref. 13:p. 613] Both the President's Private Sector Survey on Cost Control (known as the Grace Commission) and the Packard Commission had criticized the combination of research with production [Ref. 4:p. 61]. Ironically, the Carnegie Commission on Science, Technology, and Government concluded that

> ...these changes reflected a need to strengthen the 'back end' of the weapons acquisition process, including engineering development, manufacturing, contracting, and industrial-base management. But this emphasis on the back end, while necessary and desirable, has weakened the 'front end' of the process, consisting of research, technology generation, and tentative exploration of military applications. [Ref. 12:p. 20]

DOD was reorganized as a result of this legislation and is now configured as depicted in Figure 1. [Ref. 6:p. 17]

2. Under Secretary of Defense for Acquisition

The Under Secretary of Defense for Acquisition (USD(A)) has oversight responsibility of the technology base programs undertaken by the Defense Advanced Research Projects Agency (DARPA), the services and the other defense agencies. These organizations report to the USD(A) through the DDR&E.

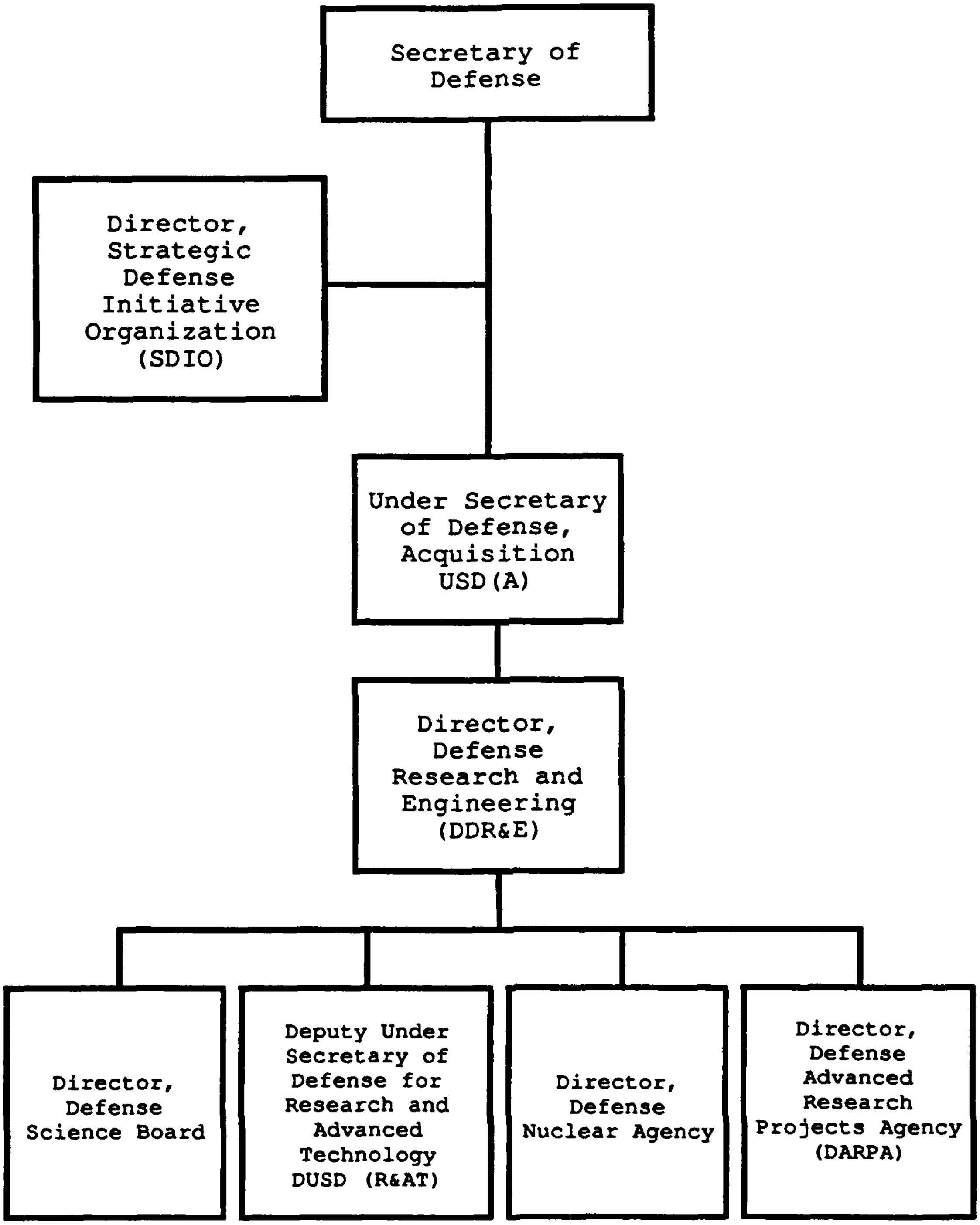

Figure 1. Organization of DOD Technology Base Management

3. Director, Defense Research and Engineering

As indicated in Figure 1, the Director, Defense Nuclear Agency, the Deputy Under Secretary of Defense, Research and Advanced Technology [DUSD (R&AT)], the Director of the Defense Science Board, and the Director of the Defense Advanced Projects Agency all report to the Director, Defense Research and Engineering (DDR&E). The DDR&E is responsible for ensuring that the technology base programs of the three services and the Defense agencies comply with OSD's technology base guidance. The DDR&E also acts as mediator in disagreements over technology base responsibilities and priorities in order to ensure they are settled so that DOD's technology objectives are upheld. According to USD(A), the DDR&E has five primary responsibilities. They are to oversee

- Development and acquisition of weapon systems through full scale engineering development.
- Force modernization.
- Design and engineering.
- Developmental test and evaluation.
- Basic research, exploratory development and advanced technology development. [Ref. 14:p. 31]

4. DUSD for Research and Advanced Technology

The DUSD (R&AT) is the services' point of contact for technology base programs. He reports to the DDR&E. The DUSD (R&AT) is responsible for

- Writing the portion of the Defense Guidance applicable to the services' technology base programs.

- Reviewing the services' two-year budget proposals.
- Responding to the services' Program Objectives Memoranda.
- Working continuously with the services to achieve mutual science and technology interests.
- Ensuring the services' technology base programs establish new research initiatives to meet long term requirements. [Ref. 14:p. 32]

E. SCIENCE AND TECHNOLOGY INVESTMENT STRATEGY

1. Overview

The Science and Technology Investment Strategy was introduced this year to satisfy Congressional requests that the Critical Technologies Plan be presented in the context of an overall S&T strategy. This document describes the S&T effort in terms of 14 functional/mission areas and 17 technology areas.

The investment strategy provides a strategic focus derived from the National Military Strategy, and the Defense Planning Guidance. The plan considers the effects of changing security, economic, and technical environments. Furthermore, it provides twelve long-term goals stated in terms of necessary military requirements 15-20 years in the future. Approximately 200 technology objectives support these goals. The twelve goals, listed in Table 2, are divided into three categories: Deterrence, Military Superiority, and Affordability. [Ref. 15:pp. 2-4]

TABLE 2. MAJOR LONG-TERM GOALS OF THE INVESTMENT STRATEGY

DETERRENCE	
Goal 1.	Weapon systems that can locate, identify, track, and target strategically relocatable targets.
Goal 2.	Worldwide, all-weather force projection capability to conduct limited warfare operations (including special operations forces and low intensity conflict) without the requirement for main operating bases, including a rapid deployment force that is logistically independent for 30 days.
Goal 3.	Defense against ballistic missiles of all ranges through non-nuclear methods and in compliance with all existing treaties.
MILITARY SUPERIORITY	
Goal 4.	Affordable, on-demand launch and orbit transfer capabilities for space-deployed assets with robust, survivable command and control links.
Goal 5.	Substantial antisubmarine warfare advantages the United States enjoyed until recent years.
Goal 6.	Worldwide, instantaneous, secure, survivable, and robust command, control, communications, and intelligence (C3I) capabilities within 20 years, to include: (a) on-demand surveillance of selected geographical areas; (b) real-time information transfer to command and control authority; and (c) responsive, secure communications from decision makers for operational implementation.
Goal 7.	Weapon systems and platforms that deny enemy targeting and allow penetration of enemy defenses by taking full advantage of signature management and electronic warfare.
Goal 8.	Enhanced, affordable close combat and air defense systems to overmatch threat systems.
Goal 9.	Affordable "brilliant weapons" which can autonomously acquire, classify, track, and destroy a broad spectrum of targets (hard fixed, hard mobile, communications nodes, etc.).
AFFORDABILITY	
Goal 10.	Operations and support resource requirements reduced by 50 percent without impairing combat capability.
Goal 11.	Manpower requirements reduced for a given military capability by 10 percent or more by 2010.
Goal 12.	Enhanced affordability, producibility, and availability for future weapons systems.

2. Critical Technologies Plan

The Critical Technologies Plan lists the 20 technologies considered the most important weapons-related technologies. These were chosen on the basis of performance, quality design, and multiple use criteria. Once selected, the 20 technologies were prioritized into three groups, A, B, and C. The A group consisted of those technologies that were perceived as the most pervasive. The B group consisted of enabling technologies, which offered the most immediate advances in weapons systems capabilities. The C group is composed of emerging technologies whose applications are in the distant future and are most difficult to assess with any certainty. Table 3 presents the 20 technologies, listed by category. [Ref. 15:p. 7]

F. THE PLANNING PROCESS

All of the services conduct annual top-down, bottom-up planning processes to modify and update the five year Program Objectives Memorandum. From the top, the services receive direction from the Defense Planning Guidance. They also receive guidance from the Critical Technologies Plan. Planning begins with a review of the previous year's activities. Inputs are also received from major commands as to deficiencies which require action. The services then decide on new research initiatives, programs to advance from

TABLE 3. CRITICAL TECHNOLOGIES

GROUP A:

- Composite Materials
- Computational Fluid Dynamics
- Data Fusion
- Passive Sensors
- Photonics
- Semiconductor Materials and Microelectronic Circuits
- Signal Processing
- Software Producibility

GROUP B:

- Air-Breathing Propulsion
- Machine Intelligence and Robotics
- Parallel Computer Architectures
- Sensitive Radars
- Signature Control
- Simulation and Modeling
- Weapon System Environment

GROUP C:

- Biotechnology Materials and Processes
- High-Energy Density Materials
- Hypervelocity Projectiles
- Pulsed Power
- Superconductivity

one budget category to the next (i.e., 6.1 to 6.2), which programs to continue, and which programs to terminate. [Ref. 4:p. 60]

G. THE DEFENSE ADVANCED PROJECTS AGENCY

The Defense Advanced Projects Agency was funded at $1269 million in 1989. DARPA was created in 1958 in response to the Soviet Union's Sputnik program. President Eisenhower felt that a different type of organization was needed because revolutionary technology crosses traditional disciplinary and organizational lines and is inherently of a high risk, high pay-off nature.

> DARPA was set up to be DOD's "corporate" research organization capable of working at the "cutting edge" of technology. DARPA's organization allows it to explore innovative applications of new technologies where the risk and payoff are both high, but where success may provide new military options or applications--or revise traditional roles and missions. In theory, since DARPA has no operational military missions, it should be able to maintain objectivity in pursuit of research ideas with promise for quantum technology advancement. [Ref. 13:p. 73]

DARPA is known for its unique and unusual ways of doing business. The agency has actively supported dual-use technology. In recent years, one of its most visible, high-profile dual-use endeavors has been its involvement with Sematech[3]. DARPA provided one-half of the $1 billion for this consortium. [Ref. 16:p. 3]

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3 Sematech is an industry-government R&D consortium to restore U.S. competitiveness in semiconductor technology.

Addressing the agency's unique business practices, Dr. Fields, former Director of DARPA, testified to Congress that one of the agency's intentions is to

> ...establish options for the Services in the defense industrial base. Unless a new product, process or service is available to the Department, our investments cannot have an effect. That is not to say that we invest up to the point of product introduction. Most commonly, we work with industry to reduce technical risk with seed funds, usually cost shared with companies, and then Service investment or private capital carries on from there... But since our focus is on defense industrial capability we form teams among for-profit and not-for-profit organizations to facilitate technology transition. In fact, since teaming is an inherent part of DARPA's business practice, we find nothing unusual in the support of consortia like SEMATECH, the MCC, or the MIT/LL/IBM/ATT superconductivity consortium. [Ref. 17:p. 4]

In FY90, Congress conferred an additional unconventional authority upon DARPA to invest $25 million a year over two years in high technology companies. DARPA can expect to receive profits from these investments in much the same manner as a venture capital firm. The $25 million a year is designed as a revolving fund. If DARPA makes money, it may reinvest it. The heart of the program is a streamlined contracting process called "flexible agreements." The first such agreement with Gazelle Microcircuits, Inc., a manufacturer of gallium arsenide computer chips, was for $4 million and took only two weeks to negotiate. Normally, more than a year is required to execute such contracts. [Ref. 18:pp. 25-26]

DARPA employs nearly 200 people, approximately half of whom are scientists, to administer its $1 billion plus

research budget. The agency does none of its own research; instead, it contracts with outside parties. Within DOD, DARPA has 52 joint programs supported by Memoranda of Understanding. Approximately 30 percent of the programs are conducted with each of the three services and 10 percent with the other Defense agencies. [Ref. 17:p. 9] DARPA's organization is tailored to its role and is frequently modified to accommodate new projects. The agency consists of the Director's office, two administrative offices and a variable number of technical offices. [Ref. 14:p. 74] DARPA's technology investment strategy is to "identify that R&D which is so risky, so long term, so difficult for an individual firm to appropriate for its own benefit, so unlikely to generate sufficient profit and yet so important to DOD that DARPA's investment is justified." [Ref. 17:p. 11]

H. STRATEGIC DEFENSE INITIATIVE ORGANIZATION

The Strategic Defense Initiative Organization (SDIO) was established in 1984, with the Director reporting directly to the Secretary of Defense. The SDIO mission is to provide the technological basis for determining the feasibility of eliminating the threat to the U.S. and its allies posed by ballistic missiles. [Ref. 6:p. 40] Like DARPA, SDIO does none of its own research. Service laboratories and contractors conduct most of the SDIO's research effort.

The SDIO budget has grown from $1.1 billion in 1984 to about $3.6 billion in 1989. The entire SDIO budget is funded with 6.3A funds. There is little doubt that a portion of SDIO's activity involves research and exploratory development, but it is difficult to determine the proportions. [Ref. 6:p. 48]

I. DEFENSE AGENCIES

The Defense agencies are the Defense Nuclear Agency; the Defense Communications Agency, the National Security Agency, the Defense Mapping Agency, and the Defense Advanced Research Projects Agency (DARPA). DARPA's contribution to the technology base is larger than all of the other Defense agencies combined. For this reason and due to its unique mission relative the DOD technology base, DARPA was addressed separately. The other Defense agencies provide funds for a little more than 6.5 percent of DOD's entire technology base. Their largest contribution is to the research program (6.1), of which their share is about 15 percent.

III. THE SERVICES' TECHNOLOGY BASE PROGRAMS

A. INTRODUCTION

Each of the services formulates its technology base programs with overall guidance from OSD. This guidance takes many forms including the Defense Planning Guide and specific service guidance. However, each service independently maintains an organizational structure for management and oversight of its technology base.

This chapter describes the different management structures used by the three services. It also discusses the relative importance of the various elements (6.1, 6.2, and 6.3A) of the technology base within each service. A discussion of each technology base investment strategy is also presented with emphasis on the different approaches the services use to manage and formulate their technology base investment strategies. The goal of this analysis is to highlight differences and determine if certain aspects of Navy and Air Force programs might benefit the Army.

B. DEPARTMENT OF THE AIR FORCE

1. General

The Air Force Chief of Staff has designated the technology base program a "corporate investment" to increase its visibility and to promote its priority for long-term

stable funding. As a "corporate investment," the technology base program is allocated a fixed fraction of the overall budget. [Ref. 14:p. 3] When the program is reviewed, it is assessed for balance and emphasis in light of all the program elements[4] that make up the program rather than on the basis of each program element individually. The Air Force's goal is to have the technology base comprise 2 percent of its total obligational authority. Currently, the technology base is classified as one of the Air Force's 35 executive programs. This designation confers upon the technology base program the stature and importance afforded other executive programs such as the B-2 Bomber. [Ref. 4:p. 72]

2. Organization

The Assistant Secretary of the Air Force for Acquisition (ASAF(A)) reports to the Secretary of the Air Force and is responsible for oversight of the Air Force's entire RDT&E program. Within the ASAF(A) office, the Director of Science and Technology (DS&T) is responsible for oversight of the service's technology base programs. [Ref. 14:p. 51]

In October 1987, the Office of the Deputy Chief of Staff for Technology and Plans (DCS T&P) was established

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[4]The program element is the basic building block in DOD's programming, planning, and budgeting system. Each program element consists of all costs associated with a research activity or weapon system.

within the Air Force Systems Command to conduct day-to-day operations and oversight of the Air Force technology base program. The DCS T&P reports to the Chief of Staff of the Air Force via the Commander, Air Force Systems Command. In forming the DCS T&P, the offices of the Deputy Chief of Staff for Science and Technology and the Deputy Chief of Staff for Plans and Programs were combined. The intent of the consolidation was to improve communication and coordination between those evaluating and planning new weapons systems and those responsible for research and advanced technology development for the new weapons systems. [Ref 16:p. 51] The Air Force Systems Command R&D Organization is depicted in Figure 2.

The DCS T&P establishes and oversees the Air Force technology base programs, but these programs must be approved by the DS&T, who ensures that the investment strategy is well-balanced and meets both near and long-term requirements of the Air Force technology users [Ref. 4:p. 72]. The Office of DCS T&P is manned by approximately 70 professionals, and consists of five major research directorates: Aircraft; Strategic and Space; Combat Support; Armament and Weapons; and Command, Control, Communications and Intelligence. [Ref. 14:pp. 51-52].

The Air Force Office of Scientific Research (AFOSR) is responsible for planning, management, and oversight of the Air Force's research (6.1) effort. In-House Laboratory

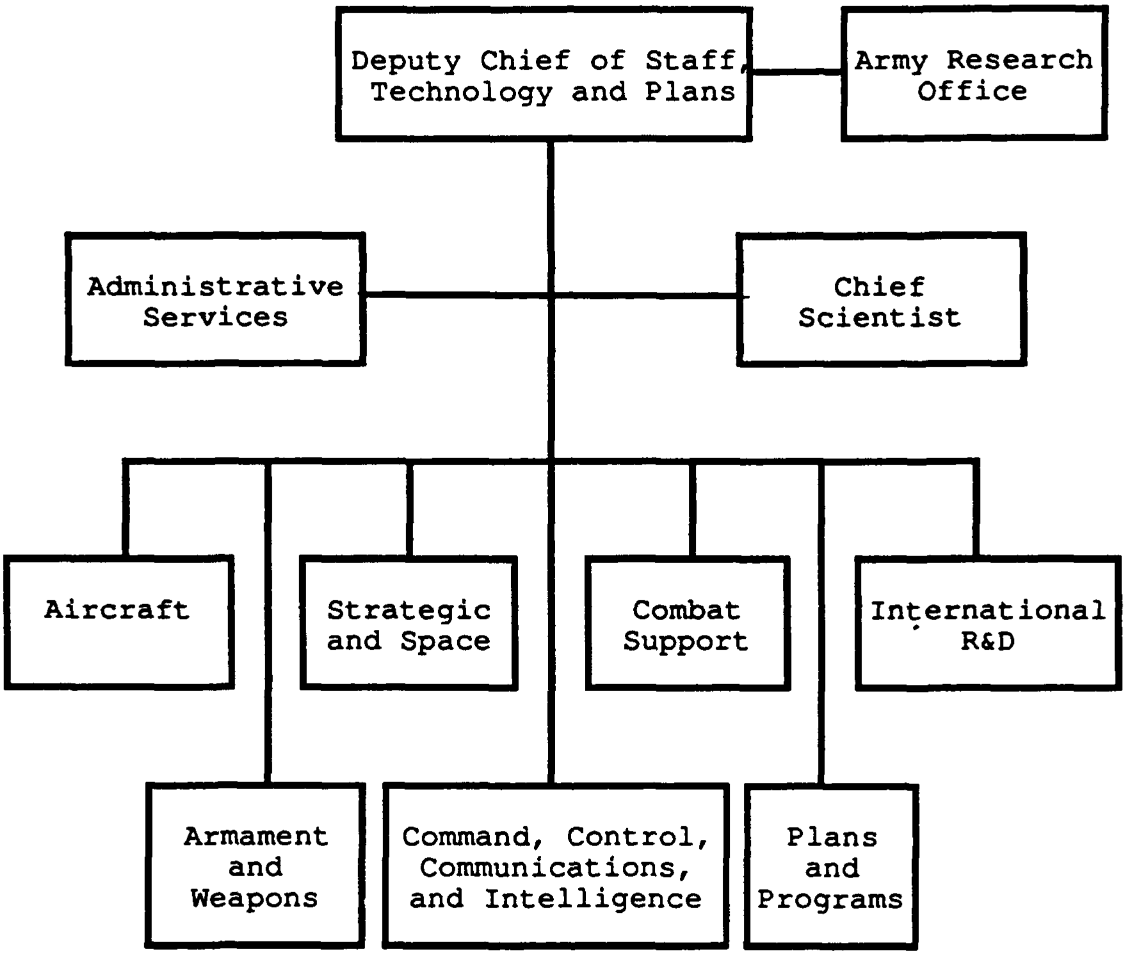

Figure 2. Air Force Systems Command R&D Organization

Independent Research (ILIR) funds are directly distributed to and managed by the individual laboratory directors. However, AFOSR retains oversight responsibility. The Commander of theAFOSR reports to the DCS T&P, who is responsible for ensuring the integration of 6.1 research with the 6.2 and 6.3A programs. The AFOSR conducts a program of research contracts and grants, oversees the research programs of the Air Force labs, and manages three subordinate units. The three subordinate units are the European Office of Aerospace Research and Development in London, the Air Force Office of Scientific Research, Far East located in Tokyo, and the Frank J. Seiler Research Laboratory in Colorado Springs. The London and Tokyo units gather information about international research and acts as liaison between the Air Force and foreign researchers. The Seiler Research Laboratory performs basic research in-house. [Ref. 14:pp. 53-54]

3. Air Force 6.1 Program

The AFOSR is responsible for management and oversight of the Air Force research (6.1) program. Its mission is to:

- Conduct and support programs in areas that support the Air Force mission.
- Maintain leadership in those research areas most vital to Air Force interests.
- Assure continued quality and excellence in basic research.
- Prevent technological surprise and guarantee technological availability.

- Transfer successful research efforts to the Air Force laboratories and commands. [Ref. 19]

In FY90, the Air Force AFOSR received $213.6 million to conduct its mission. Of this amount, the Air Force allocated $189 million for the Defense Research Sciences program element and it was used to fund research in six major disciplines. Another $24.6 million was suballocated by DOD to fund the University Research Initiative program and 61.6 percent of these funds ($15 million) were devoted to multidisciplinary research. The other University Research Initiative funds were distributed to the Summer Faculty Research Program, the Research Initiation Program, the Laboratory Graduate Fellowship Program, and the National Defense Science and Engineering Graduate Fellowship Program. [Ref. 19]

Universities conduct the bulk of the Air Force's research activities. In FY90, 60 percent of AFOSR's research funds supported university research. The remaining funds went to industry (20 percent), ILIR (15 percent), and 5 percent were for maintenance of the AFOSR infrastructure. In FY90, Air Force research (6.1) received slightly more than 13 percent of the total technology base allocation. [Ref. 19]

4. Air Force 6.2 and 6.3A Programs

The Air Force DCS T&P provides oversight for the service's 6.1 and 6.2 programs. However, it takes an especially active role in the direction of the Air Force Advanced Technology Development (ATD) program. The Air Force

Systems Command has five major product divisions. They are the Electronic Systems Division, the Armament Division, the Human Systems Division, the Aeronautical Systems Division, and the Space Division. Since 1980, each of these divisions has been assigned responsibility for one or more of the 14 Air Force laboratories which perform activities primarily in support of that division's mission. Similarly, each of the research directorates within DCS T&P works closely with a specific product division and has oversight and coordination responsibility for that division's laboratories. [Ref. 4:p. 74]

The individual laboratory director is confronted with a chain of command which dictates dual reporting requirements. He reports to both the parent product division and his responsible DCS T&P research directorate. This does not mean that the laboratories work exclusively for a single product division or a single research directorate. The interdisciplinary nature of 6.2 and 6.3A necessarily requires the laboratory directors to manage programs for a number of product divisions. [Ref. 4:p. 74]

The Air Force rationale for placing laboratories under the control of product divisions is to facilitate communication between the developers and the ultimate users, claiming that this arrangement improves long range technology base investment planning. With the assertion that this arrangement provides for a more timely transition of mature

technologies into fielded weapons systems, the Air Force believes this arrangement reduces both costs and development time. [Ref. 4:p. 75]

Air Force emphasis on 6.3A programs is demonstrated by their growth in nominal dollars from $159 million in FY75 to $758 million in FY89 [Ref. 4:p. 75]. Advanced exploratory development accounted for 49 percent of the total technology base program in FY89. In FY90 only $639 million was committed to the 6.3A program. This represents 46 percent of the total technology base funds. Most of this activity is performed by defense industries through contracts administered by the product division laboratories. The Air Force contends that contractor participation in the successful development and testing of new technology results in more rapid contractor incorporation of technological advances. [Ref. 16:pp. 58-59]

The Air Force also supports the largest exploratory research (6.2) effort in absolute terms despite the fact that it allocates a smaller proportion of its technology base to this budget category than the other services. It allocates about 41 percent of its technology base resources to 6.2 programs and in FY90 this amounted to $566 million.

5. Air Force Investment Strategy

The Air Force Technology Base Investment Strategy is characterized by the following observations:

- The entire technology base program is treated as a "corporate investment." When budgets are examined, the program is viewed as a whole for proper balance and emphasis.
- The goal is to fund the technology base program at two percent of Air Force total obligational authority.
- The technology base program is classified as an executive Air Force program. This designation institutionalizes the program's stature and criticality.
- The technology base program emphasizes technology transition. This explains why nearly 50 percent of the technology base funds are used for 6.3A programs. [Ref. 4:p. 72]

Like the other services, the Air Force conducts an iterative annual top-down, bottom-up planning and review exercise. It augments this process with insights gained from Project Forecast II. The purpose of Forecast II was to identify potential technologies that could "change the nature and design of future systems, while concomitantly improving the Air Force's warfighting capabilities." [Ref. 14:p. 59] This project was established by the Secretary of the Air Force and chaired by the Commander of Air Force Systems Command. Approximately 175 military and civilian experts from various commands participated. Forty technological initiatives were identified for technology base funding support. Research progress in each of these areas is monitored and changes in emphasis are made as the technologies mature. The purpose of this ongoing planning activity is to prevent technological surprise and to remain alert to new technological opportunities. [Ref. 14:p. 59]

C. DEPARTMENT OF THE NAVY

1. Organization

Figure 3 depicts the Navy's technology base organization. The Chief of Naval Research is the scientific advisor to the Chief of Naval Operations and the Commandant of the Marine Corps. He reports to the Assistant Secretary of the Navy for Research, Development and Acquisition. The Office of Chief of Naval Research is composed of the Office of Naval Research (ONR), the Office of Naval Technology (ONT), and the newly created Office of Advanced Technology (OAT). [Ref. 22] Since 1985, the Chief of Naval Research has also had oversight responsibility for all of the Navy's laboratories [Ref. 4:p. 64].

ONR funds, manages, and oversees the Navy's basic research effort. ONR is composed of four research directorates: Mathematics and Physical Sciences, Environmental Sciences, Engineering, and Life Sciences. A fifth directorate, the Applied Research and Technology Directorate, is responsible "for adapting and extending basic research toward applied research, thereby helping to transition research results into the Navy's exploratory development program." [Ref. 4:p. 67] The Navy is the only service with a research directorate that performs this activity. ONR also supports, supervises and oversees four Navy labs: the Naval Research Laboratory, the National

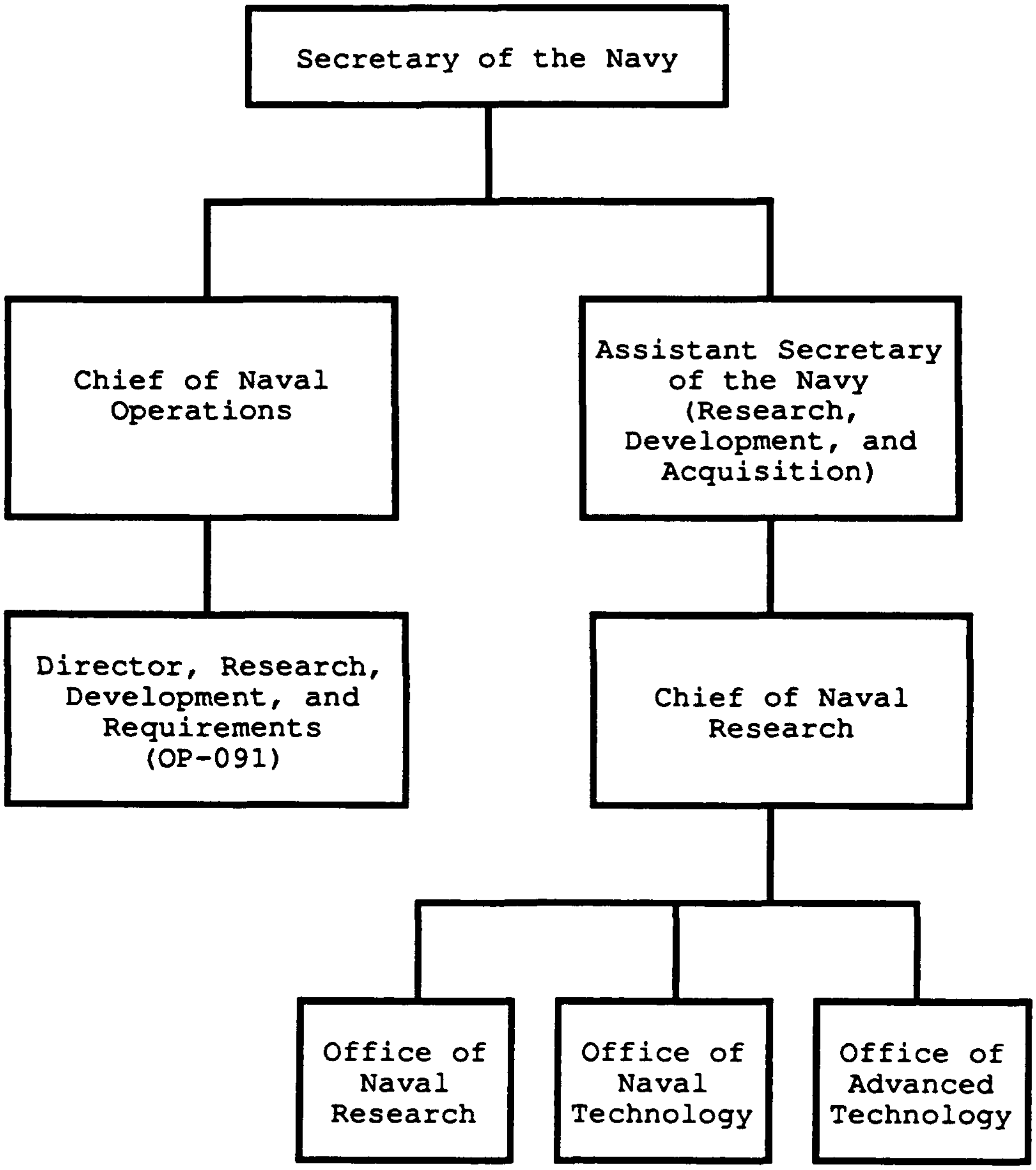

Figure 3. Navy Organization for Science and Technology

Oceanographic Research and Development Activity, the Institute for Naval Oceanography, and the Navy Environmental Prediction Research Facility [Ref. 4:p. 66].

ONT funds, manages and oversees the Navy's exploratory development activities. ONT was created in 1980 "to provide for a more clearly defined process of planning, execution and transition of programs within the technology base and into advanced technology development." [Ref. 14:p. 42] ONT consists of six major directorates: Antiair/Antisurface Warfare and Surface/Aerospace Technology Directorate; Antisubmarine Warfare and Undersea Technology Directorate; Support Technologies Directorate; Low Observables Directorate; Ocean Science and Technology Directorate; and the Industry Independent R&D Directorate. About 80 percent of the Navy's 6.2 program is funded through the first three directorates. The other three directorates are primarily tasked with oversight and coordination of related 6.2 programs. [Ref. 14:p. 45]

The Navy is the only service that manages its 6.3A program separately from its 6.1 and 6.2 programs. The 6.3A program is managed by the Director, Research, Development and Requirements (Test and Evaluation), who is also referred to as OP-091. He resides within the office of the Assistant Secretary of the Navy for Research, Systems and Engineering.and is also responsible for the conduct of day-to-day 6.3A operations. [Ref. 4:p. 70]

2. Navy 6.1 Program

ONR supports a much larger research program than the other services. According to the proposed FY91 budget submissions, the Navy will fund 41 percent of DOD's basic research effort. Moreover, the Navy POM calls for continued real growth in the 6.1 program through FY97. [Ref. 21]

The Navy's research program supports theoretical and experimental research in fields such as physical and mathematical sciences, engineering sciences, life sciences, and ocean sciences. Funds are allocated among 16 science disciplines and are cross-referenced to 17 warfare areas. Universities conduct 53 percent of the Navy's research. Other research performers include ONR laboratories (22 percent), other Navy laboratories (12 percent), and industry (13 percent). [Ref. 21]

The Navy's laboratories perform much more of their research in-house than those of the other services. Many Navy laboratories not only have the capability to perform in-house research and exploratory development, but can also "carry a design almost to the production level through the more 'mature' stages of advanced systems development (6.3B) and engineering development (6.4)." [Ref. 4:p. 88]

ONR supports a larger ILIR program than the other services. In FY91, the Navy proposes to fund its ILIR program at $26.8 million. This represents nearly seven percent of the entire 6.1 budget. DRS will receive another

$374.4 million bringing the total Navy 6.1 program to $401.2 million. The Navy also expects DOD to allocate $24.0 million to its University Research Initiative program. [Ref. 21]

3. Navy 6.2 Program

The Navy's exploratory development program is managed by the Office of Naval Technology (ONT) within OCNR. ONT is responsible for activities such as program planning, approval, funding, review and evaluation. [Ref. 14:p. 43] The Navy currently supports the smallest exploratory development program of the three services. However, the Navy's 1992 POM calls for real increases in funding for exploratory development through FY97. According to the POM, funding would approach $600 million in FY97. [Ref. 20]

Like its research program, the Navy performs a much larger portion of its 6.2 program in-house than the other services. In FY90, the Navy performed 47 percent of its 6.2 program in its own laboratories and another 4 percent was conducted by other government agencies. Other performers were defense contractors (42 percent) and universities (8 percent). [Ref. 20]

ONT sponsors an Independent Exploratory Development (IED) program, which is similar in nature and purpose to the 6.1 In-House Laboratory Independent Laboratory funding element. The major distinction is that IED is supported with 6.2 funds and is used to support 6.2 activities. In the FY91 budget submission, IED is funded at 3 percent of the 6.2

budget and provides the technical directors of the Navy R&D Centers with discretionary funds to support activities to achieve their centers' assigned missions. [Ref. 11:p. 12] "Normally, a specific program cannot be supported with Independent Exploratory Development Funding for more than three years." [Ref. 4:p. 70]

4. Navy 6.3A Program

In its FY91 budget submission, the Navy requested $201.9 million for execution of its advanced exploratory development program (6.3A). This is less than one third of the Air Force's request and less than 40 percent of the Army's proposed 6.3A funding level.

Day-to-day oversight of the 6.3A program is conducted by OP-091. In August of 1990, the Chief of Naval Research established the Office of Advanced Technology in compliance with the approved Defense Management Report Navy Implementation Plan of 1 October 1989. However, the function and mission of this organization are yet to be determined. [Ref. 22]

The Navy's advanced exploratory development program is comprised of advanced technology demonstrations (ATD's) which account for about 25 percent of the 6.3A program and advanced technology development programs which account for the other 75 percent of the program. According to OP-091, Navy policy requires full funding of each approved ATD. When cuts must be made, vertical cuts will be enforced in reverse priority

order. Each ATD project is managed by a single Systems Command and the program sponsor cannot transfer funds from an ATD project for use as an offset in another program. The duration of ATD's is from one to three years.

5. Navy Investment Strategy

ONR, ONT, and OP-091 independently promulgate 6.1, 6.2, and 6.3A investment strategies respectively. They are very similar in many respects and the relevant points of each are presented below.

a. The Navy 6.1 Investment Strategy

The Navy research investment strategy seeks to support the fleet of 2020 by

- Maintaining a broad, versatile program in all science areas of potential naval relevance in order to create and/or exploit scientific breakthroughs and respond to critical fleet needs.
- Emphasize investments in ocean sciences, advanced materials, and information sciences to accelerate technology transition in high Navy priority areas.
- Investing 60 percent of funding in evolutionary research, 15 percent in high risk/high payoff revolutionary effort, and 25 percent in research closely associated with fleet applications.
- Providing stable, predictable support to sponsored investigators...and nurturing a strong and responsive in-house laboratory research capability.
- Leveraging non-Navy R&D programs to optimize scarce 6.1N resources.
- Accelerating transitions to meet critical scientific gaps in essential fleet programs. [Ref. 21]

ONR has a policy of broad, flexible resource allocation across diverse science disciplines and warfare

areas. It also believes that certain sciences can be projected to be important to given needs, and specific investments are made for the purpose of bridging gaps between Navy requirements and existing technology. [Ref. 25]

ONR believes a prudent investment strategy requires provisions to accommodate the cyclic nature of funding. "ONR addresses this by dealing with short-term funding excursions through the external programs, and maintaining long-term stability in the Navy laboratories." [Ref. 23] With this approach, ONR retains flexibility and maintains a strong in-house capability vital to Navy interests.

b. The Navy 6.2 Investment Strategy

The Office of Naval Technology's goal is to provide the Navy and Marine Corps with "new and improved fleet capabilities in the most cost-effective and timely manner." [Ref. 11:p. 9] This goal is achieved by developing technology to

- Keep ahead of the projected threat.
- Provide affordable system options.
- Reduce fleet operating costs.
- Avoid technological surprise. [Ref. 11:p. 9]

In more specific terms, the corporate investment strategy for the DON 6.2 Program is to:

- Ensure that, within available resources, the technology needs for each naval warfare area are met, balancing the portfolio over short-, mid-, and long-term needs,

generally emphasizing weapons and surveillance technologies, and their related countermeasures and environmental support factors.

- Reflect Navy's commitment to ASW as its number-one priority in the 6.2 investment posture.

- Consider other-service investments in areas of common interest.

- Provide moderate, sustained support for platform technologies that meet unique Navy and/or Marine Corps needs.

  - Consider DARPA investments in submarine technology.

  - Consider Air Force, industry investments in aerospace technologies.

- Provide stable, sustained support for mission support areas, such as personnel/training, logistics, biomedical, naval oceanography, environmental protection and chemical/biological (CB) defense, with additional targeted investment in selected high-payoff areas.

  - Coordinate investment with other services in areas of common interest, e.g., biomedical and CB defense.

- Ensure a stable technology base in core technology areas such as electronic devices, advanced materials, human factors and computer technology, with special emphasis on growing the latter based on a Navy-unique niche investment strategy.

  - Maintain present investment level in DOD critical technologies (~30 percent).

- Rebuild/maintain the Independent Exploratory Development (IED) Program at a level equal to 5 percent of the 6.2 funds managed by those laboratories participating in the IED program. [Ref. 11:pp. 10-11]

c. The Navy 6.3A Investment Strategy

The Navy's 6.3A investment strategy calls for

- Increasing the ATD portion of the 6.3A account.

- Attaining significant real growth in ATDS, ASW, and electric drive technology.

- Maintaining the baseline non-ATD 6.3A program.

D. DEPARTMENT OF THE ARMY

1. Organization

The Army technology base management organization is displayed in Figure 4. The Deputy for Technology and Assessment reports to the Assistant Secretary of the Army for Research, Development and Acquisition and is responsible for planning, developing, and executing research (6.1), exploratory development (6.2), and advanced exploratory development programs (6.3A) [Ref. 4:p. 76].

The Army technology base organization is much more complicated and fragmented than those of the other services. The program is administered by four functional organizations: the Army Material Command (AMC), the Surgeon General of the Army (SGA), the Army Corps of Engineers (COE), and the Deputy Chief of Staff for Personnel (DCSPER). These organizations employ about 15,000 scientists and engineers. For oversight purposes, the directors of these four commands report to the the Deputy for Technology and Assessment. [Ref 27:p. 8]

The Army Materiel Command receives 73 percent of all technology base funding [Ref. 25] and is responsible for the research, development, and acquisition of combat and support equipment. AMC is analogous to the Air Force Systems Command and is similarly composed of subordinate mission-specific "buying" commands which run laboratories and technology base programs. [Ref. 4:p. 22] The Army Laboratory Command

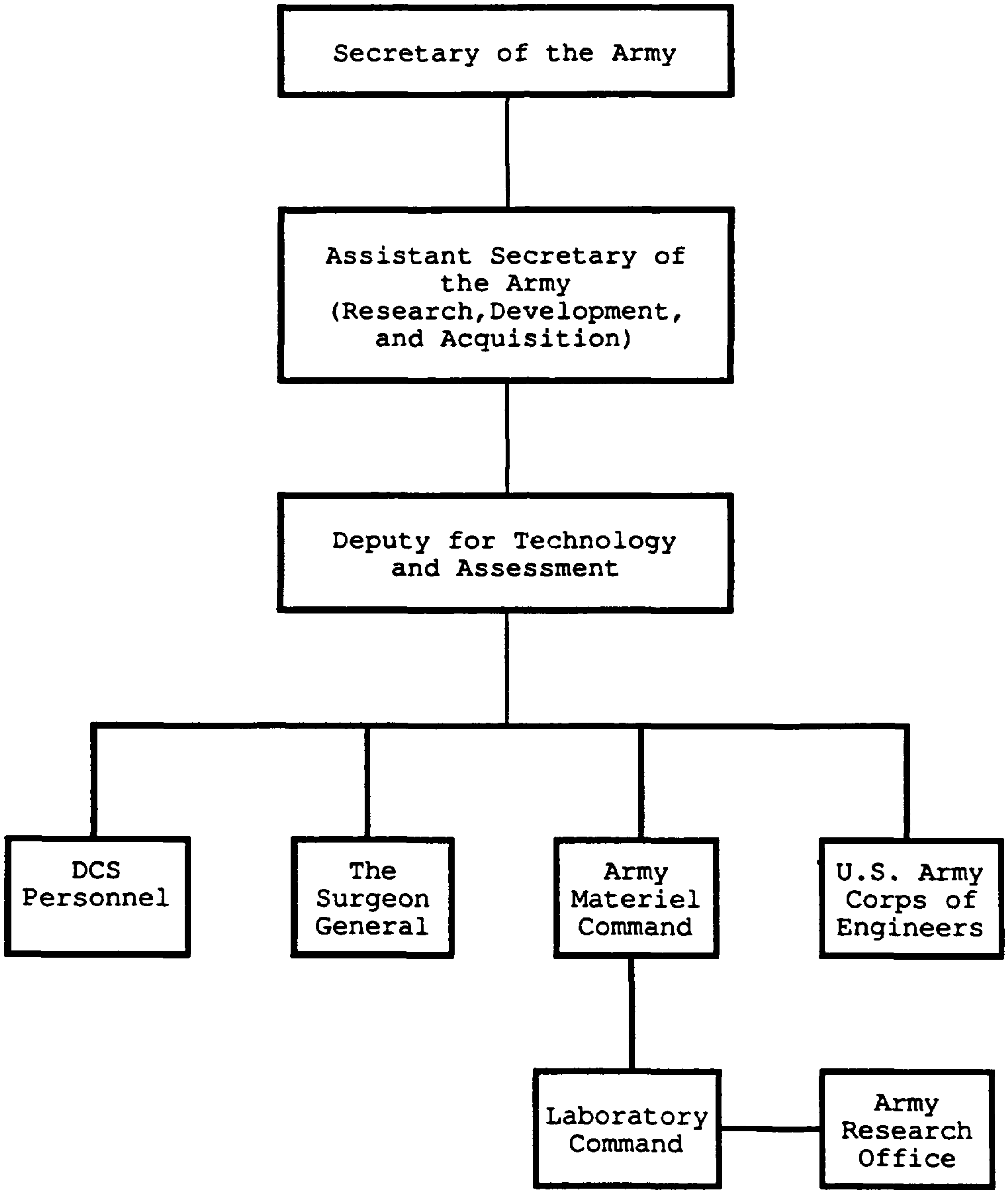

Figure 4. Army Research and Development Organization

(LABCOM) is also subordinate to AMC, but its purpose is to "serve as the corporate center for acquisition of generic science and technology in support of all AMC's commodity commands." [Ref. 24:p. 8] LABCOM has seven laboratories that employ about 1,800 scientists and engineers. In addition to managing the research and technology programs of his own laboratories, the LABCOM Commander is also responsible for oversight of AMC's entire S&T program in his capacity as Deputy Chief of Staff for Technology Planning and Management for AMC. [Ref. 24:p. 8] The Army Research Office (ARO) also reports to the LABCOM Commander. ARO serves as the Army's major interface with the university community and manages AMC's research (6.1) program.

2. Army 6.1 Program

The Army is the only service that manages its research program from more than one office. Four major commands receive 6.1 funds - TSG, AMC, COE, and DCSPER. Each of these recipients has independent entities for management and oversight of the funds allocated to it. According to the FY91 budget submission, AMC will receive the largest portion, approximately 70 percent of the basic research funds. TSG will receive approximately 22 percent, COE 6 percent, and DSCPER the remaining 2 percent. These percentages are approximations and may fluctuate from year to year, but they convey the general distribution of the Army's annual 6.1 allocation. [Ref. 25]

The Army Research Office (ARO) is primarily responsible for the management and oversight of AMC's research program. It directly manages approximately half of AMC's research allocation. The other half is managed by AMC's laboratories and centers. Although ARO does not directly manage the portion that goes to the labs and centers, it does make recommendations to the Deputy for Technology and Assessment regarding the size and content of those programs and projects. [Ref. 4:p. 77]

The ARO staff consists of 121 people, of which 47 are scientists or engineers [Ref. 25]. This staff sponsors a program which consists of a mix of short and long-term projects. ARO works closely with the Army Training and Doctrine Command (TRADOC) and its schools to shape its program according to mission area needs. [Ref. 4:p. 77]

Since 1982, ARO has supported Army Centers of Excellence at selected colleges and universities. Research in specific disciplines is funded from five to ten years. Currently, these disciplines include electronics, rotary wing technology, optics, mathematics, artificial intelligence, high performance computing and photonics. [Ref. 25]

In FY91, the Army's technology base will be funded at $1281 million. Of this, $189 million (15 percent) IS dedicated to basic research. In the FY91 research (6.1) budget request, DRS accounts for $180 million and the remaining $9 million is allocated to the ILIR program. The

Army also expects to receive an additional $22 million from OSD for its University Research Initiative program. [Ref. 25]

In FY88 and FY89, the Army did not fund the In-House Laboratory Independent Research program element. Funding resumed in FY90 with an appropriation of $9.1 million. The funds were distributed to AMC ($5.6 million), COE ($0.9 million) and TSG ($2.6 million). [Ref. 26:p. 1] In May 1989, the Assistant Secretary of the Army for Research, Development and Acquisition directed that the ILIR program "will be targeted at no less than 10 percent of the total 6.1 budget to be attained by FY94 and maintained at or above that level thereafter." [Ref. 26: 4] He also directed that "all ILIR funds appropriated by Congress will be made available for that purpose...ILIR funds will not be used to make up deficiencies in planned mission programs." [Ref. 26:p. 4]

3. Army 6.2 Program

The Army's FY91 budget requested $580 million for its 6.2 activities (Table 4). This accounts for nearly 45 percent of the Army's technology base funds. As a proportion of its total technology base resources, this is more than either of the other services allocates to its exploratory development program.

AMC's LABCOM retains responsibility for oversight and management of the majority of the Army's 6.2 allocation. However, the Army Training and Doctrine Command (TRADOC) is largely responsible for the selection of specific projects

and technologies which will receive funding. TRADOC uses a procedure known as Concepts Based Requirements System (CBRS). This procedure is performed annually and is explained in the following paragraphs [Ref. 27:pp. 6-8].

Each year TRADOC develops and promulgates a concept of warfighting. Once approved, this concept is used by the TRADOC schools and centers to prepare Mission Area Analyses (MAA's) in each of the Army's 13 major mission areas. In performing its MAA, each of the schools and centers compares the warfighting requirements of the concept with their current warfighting capabilities. The differences between the requirements and the capabilities are categorized as battlefield deficiencies. The output of each MAA is a prioritized list of battlefield deficiencies.

TRADOC Headquarters compiles all of the MAA's and assesses the deficiencies from a global perspective. It then prepares a final prioritized list of all of the battlefield deficiencies and publishes these deficiencies in the Battlefield Development Plan (BDP). The BDP is the driver for changes in doctrine, organization, training, and materiel. Deficiencies become an AMC material development or acquisition requirement only if they cannot be overcome by changes in doctrine, organization, or training.

Within AMC, there are Mission Area Managers (MAM's) who work closely with the TRADOC organization responsible for the MAA. The MAM's are responsible for preparing Mission

Area Material Plans (MAMP's) that are subjected to a series of reviews to select work packages to appear in the technology base. The BDP is the document that drives this process. "The MAMP process provides AMC HQ with a global view of the material requirements of the Army as well as a better means to exercise judgements regarding the value of specific technologies." [Ref. 27:p. 8]

4. Army 6.3A Program

In FY91, the Army intends to commit $512 million to its advanced exploratory development (6.3A) program. This represents 40 percent of the Army's total S&T program. Like the 6.1 and 6.2 programs, this program does not receive oversight and management from a single source. Advanced exploratory development work is conducted by COE, AMC, TSG, and DCSPER. However, the majority of the 6.3A effort is conducted by AMC; and LABCOM's Technology Management and Planning Directorate is responsible for its oversight and management.

5. The Army Technology Base Investment Strategy

The Army Technology Base Master Plan guides the Army's technology base investment strategy. It describes a vision for defining, developing and acquiring state of the art technology to assure U.S. Army superiority in the event of war. "It is a resource constrained action plan for assuring that the U.S. Army is the most deployable force in the world." [Ref. 28:p. 12]

The *Army Technology Base Master Plan* is built on a framework of principles that establish threat assessment, technological forecasts, user requirements, resources and specific science and technology objectives. The principles of the plan are as follows:

- Ensure that the technology base program supports the Army's future warfighting requirements.
- Balance the technology base between near-, mid-, and far-term needs; between technology push and requirements pull; and between weapons systems and other battlefield requirements.
- Distribute technology base resources in accordance with the Technology Base Investment Strategy: next-generation and future systems, systemic issues, supporting capabilities, and key emerging technologies.
- Seize and retain the technology initiative.
- Enhance the return on investment of Army tech base dollars by leveraging outside resources and by conducting joint and cooperative ventures with other services and government agencies, our allies, industry, and academia.
- Reduce the time from system concept to successful fielding through the conduct of focused Advanced Technology Transition Demonstrations.
- Restore stability to technology base funding by assuring a commitment to long-term goals.
- Provide top-down guidance to create an atmosphere that fosters technology initiative and the pursuit of promising, innovative opportunities. [Ref. 28:p. 12]

The Army technology base investment strategy identifies four areas of investment: emerging technologies, next generation and future systems, systemic issues and supporting capabilities.

The Army has determined that 50 percent of its investments will be used to identify next generation and future systems. The purpose of this investment is to speed introduction of advanced technologies into new and improved combat systems. This is accomplished by conducting Advanced Technology Transition Demonstrations. These demonstrations are the bridge between the user and the technology developer and serve as "proof of principle" that technology is mature enough to meet specific operational requirements and that the risk of proceeding with development is acceptable. [Ref. 28:p. 7]

> ....Next generation systems are usually defined as those beyond the systems currently in engineering development, while future systems are the ones a generation beyond that. According to the Army, the difference between next generation and future systems is less critical than the fact that differentiating between relatively well defined and more conceptual solutions to battlefield problems provides a range of targets for technology base efforts from mid-range (next five years) to long term (10-15 years). [Ref. 14:p. 68]

The second largest segment of the investment strategy is emerging technologies. This receives 25 percent of the technology base allocation. Emerging technologies represent research efforts which tend to be non-system specific and show great potential to enhance battlefield capabilities. [Ref. 28:pp. 2-3] Most of the emerging technology activities are "focused on longer-term technology base activities, exploring new technological concepts that could be used by the Army 15-30 years in the future." [Ref. 14:p. 68] The 13

emerging technologies that have been identified for special emphasis are robotics, artificial intelligence, advanced signal processing and computing, microelectronics, power generation, armor protection, advanced materials, biotechnology, neuroscience, low-observables, space technology, directed energy technology, and advanced propulsion [Ref. 28:p. 4].

The third area of emphasis is systemic or chronic problems. This investment initiative receives 15 percent of technology base funding and addresses issues such as corrosion prevention and manufacturing problems. Solution of systemic problems may not be as glamorous as developing new systems, but the Army recognizes that it is essential to its mission that they be addressed. [Ref. 14:p. 68]

The fourth investment area, supporting capabilities, represents the Army's recognition that the R&D infrastructure must have modern facilities and test equipment in order to ensure continued leadership in battlefield innovations. Ten percent of technology base funding is devoted to maintenance and improvement of the research infrastructure. [Ref. 14:p. 68]

Since 1988, the Army has been using wargaming exercises to "identify and select the most promising technologies for investment, and to assess our future Tech Base Investment Strategy and its relationship to the user's vision for warfare in 2015." [Ref. 29] These exercises are

called Technology Base Seminar War Games. The most recent war game was held in April and June 1990 and consisted of two phases. The first phase had two objectives. One was to identify the most promising next generation and future systems from among those conceptualized by the technology community. The second was to conceptually identify additional systems required to meet the threat of 2015.

The second phase of the Technology Base Seminar War Game assessed the operational impact of the next generation and future systems which were selected in Phase One. "This phase was designed to gain insights into the value and implications of these systems in various operational environments, and to illuminate NGS/FS technology attributes and performance characteristics which provide the highest degree of force effectiveness in a resource constrained environment." [Ref. 29]

Pace and Moran point out a number of advantages of technology gaming as a forecasting tool. Some of the advantages are:

- It provides an opportunity for innovation normally missing in the otherwise busy lives of R&D leaders.
- It is a valuable tool for developing consensus, especially in terms of what the issues are or how the problem should be stated.
- It can easily address questions and issues which are not well defined because of its flexible and adaptive nature.
- It allows examination of command and control processes when there is incomplete (and possibly erroneous) information. [Ref. 30:pp. 243-44]

Pace and Moran also concede that technology gaming has its limitations. It is not useful for qualitative analysis. Furthermore, it is not magic and requires considerable resources to be effectively employed. However, they conclude that technology gaming's advantages are so overwhelming that it will eventually become an institutional part of the Navy's R&D investment process also. [Ref. 30:p. 249]

E. SUMMARY

Table 4 presents FY90 and FY91 budget comparisons for the three services. Of particular note is the fact that the Army allocates a significantly larger portion of its RDT&E budget to its technology base than does the Navy or the Air Force. Table 5 provides a summary of the major features of the Army, Navy, and Air Force technology base programs.

TABLE 4. FY90-91 TECHNOLOGY BASE BUDGET COMPARISON ($M)

	ARMY	AIR FORCE	NAVY
TOTAL RDT&E			
FY90	5418.7	13496.9	9465.8
FY91	6025.9	13276.3	9102.4
S&T INVESTMENT			
FY90	1273.7 (23%)[1]	1394.5 (10%)	1020.3 (11%)
FY91	1280.7 (21%)	1427.7 (11%)	1069.4 (12%)
6.1 INVESTMENT			
FY90	181.6 (14%)[2]	189.6 (14%)	361.0 (35%)
FY91	188.9 (15%)	201.5 (14%)	401.2 (37%)
6.2 INVESTMENT			
FY90	547.8 (43%)	565.7 (41%)	443.5 (43%)
FY91	580.0 (45%)	580.1 (41%)	466.3 (44%)
6.3A INVESTMENT			
FY90	544.3 (43%)	639.2 (45%)	215.8 (22%)
FY91	511.8 (40%)	646.1 (45%)	201.9 (19%)

[1]S&T investment as a percentage of total RDT&E.

[2]Investment allocation as a percentage of S&T resources.

Source: Office of the CNO (OP-091)

TABLE 5. COMPARISON OF SERVICE TECHNOLOGY BASE PROGRAMS

Air Force	Navy	Army
	ORGANIZATION	
• Deputy Chief of Staff for Technology and Plans oversees entire Air Force program. - Oversight is provided by a single office • DCS T&P is located within Air Force Systems Command. - Close coordination is maintained with "buying" commands.	• OCNR and OP-091 are higher in organization than counterparts in other services. • 6.1 and 6.2 programs are managed separately from 6.3A program. • The Navy has removed its research activities further from development activities than the other services.	• Organization is more decentralized than other services. • Oversight and management provided by four organizations - AMC, COE, SGA, and DCSPER. • S&T organization is closely aligned with "buying" commands. • LABCOM, which oversees 75% of S&T program, reports to AMC.
	RESEARCH (6.1) PROGRAM	
• Air Force Office of Scientific Research is responsible for entire 6.1 program. • Research receives 14% of S&T funds. • Research funds are allocated to the following: - universities (60%) - Industry (20%) - In-house laboratories (15%) - Maintenance of infrastructure (5%)	• The Office of Naval Research oversees entire 6.1 program. • Research receives about 35% of S&T funds. • ONR labs are capable of conducting a wider range of activities than counterparts in the other services . • The Navy supports a larger In-House Laboratory Independent Research program than the other services. • Research is conducted by the following: - Universities (53%) - ONR laboratories (22%) - other Navy labs (12%) - Industry (13%)	• The Army is the only service that manages research from more than one office. - The Army Research Office (ARO) oversees AMC's research budget (70% of total Army 6.1 funds). • ARO supports 7 Centers of Excellence. • Research receives 15% of S&T funds. • In-House Laboratory Independent Research was funded at 5% in FY90 and will account for no less than 10% of 6.1 funds by FY94.

TABLE 5. COMPARISON OF SERVICE TECHNOLOGY BASE PROGRAMS (cont.)

Air Force	Navy	Army
Exploratory Development Program (6.2)		
• The Air Force 6.2 program accounts for 41% of RDT&E funds. - $566 million in FY 90.	• The Office of Naval Technology manages the Navy's entire 6.2 Program. • The Navy 6.2 program accounts for 43% of RDT&E funds. - $433.5 million in FY 90. • The Navy conducts a larger portion (47%) of its 6.2 program in-house than the other services. • The Navy has an Independent Exploratory Development program that provides laboratory directors with discretionary funds for 6.2 projects.	• The Army 6.2 program accounts for 43% of RDT&E funds. - $547.8 million in FY 90. • The Army uses a Concepts Based Requirements System to select projects and technologies for funding.
Advanced Exploratory Development Program (6.3A)		
• The Air Force emphasizes its 6.3A program. • The Air Force 6.3A program accounts for 45% of RDT&E funds.	• The Navy has a much smaller 6.3A program budget than the other services. • The Navy 6.3A program accounts for only 22% of RDT&E funds.	• Like the 6.1 and 6.2 programs, the 6.3A program does not receive oversight and management from a single source. • The Army 6.3A program accounts for 43% of RDT&E funds.

TABLE 5. COMPARISON OF SERVICE TECHNOLOGY BASE PROGRAMS (cont.)

Air Force	Navy	Army
	Overall Technology Base Funding	
• The Air Force allocates about 10% of RDT&E funds to its technology base program. • In absolute monetary terms, the Air Force supports the largest technology base program. - $1394.5 million in FY 90	• The Navy allocates about 11% of RDT&E funds to its technology base program. - $1020.3 million in FY 90	• As a percentage of RDT&E, the Army supports the largest technology base program. • The Army allocates about 23% of RDT&E funds to its technology base program. - $1273.7 million in FY 90
	Investment Strategy	
• The Air Force has designated its technology base program as an executive program and a "corporate investment", which ensures that it receives a fixed portion of the overall Air Force budget. • An Air Force goal is to fund the technology base at 2 percent of Air Force total obligational authority. • Technology transition is a top priority.	• The Navy strategy emphasizes a strong research (6.1) program. • The Navy strategy also emphasizes in-house research efforts. • The Navy investment strategy calls for real growth in 6.3A funding.	• The Army investment strategy is guided by the Army Technology Base Master Plan. • The Army investment strategy identifies four areas of investment: emerging technologies, next generation and future systems (NGFS), systemic issues and supporting capabilities. Emphasis is as follows: - Emerging technologies (25%) - NGFS (50%) - Systemic issues (15%) - Supporting capabilities (10%) • The Army uses wargaming to identify and select technologies for investment.

IV. TECHNOLOGY BASE ISSUES

In this chapter, three issues relevant to the technology base will be examined. The issues are:

- The trend of decreased funding for technology base programs.
- The perception that technology base managers are risk averse.
- The debate on the best way to ensure continued technical innovation.

Each issue will be discussed in the following sections.

A. TECHNOLOGY BASE FUNDING

Technology base funding has been a concern of many in the last few years. As Table 6 indicates, technology base funding, including SDI, increased 225 percent in constant dollars between 1970 and 1989. During this same period, RDT&E funding increased 169 percent. This gives the erroneous impression that "front-end" investments received much more emphasis than "back-end" initiatives during this time.

As is the case in Table 6, SDI funding is often reported separately from other 6.3A efforts. In recent years, SDI accounted for about 40 percent of the technology base funding and almost all of the increase in technology base funding since 1984. However, "SDI is outside of the process that controls the rest of DOD's technology base program." [Ref.

TABLE 6. DOD TECHNOLOGY BASE FUNDING TRENDS (millions 1982$)

Year	6.1	6.2	6.3A[1]	SDIO[2]	Total Without SDI	Total With SDI	RDT&E[3]
1970	779	2418			3197		NA
1971	728	2238			2966		NA
1972	712	2414			3126		NA
1973	629	2306			2935		NA
1974	579	2126	567		3273		NA
1975	530	1923	631		3084		NA
1976	528	1902	677		3107		NA
1977	556	1947	734		3237		NA
1978	576	1937	697		3210		NA
1979	608	1972	725		3306		NA
1980	653	2021	676		3350		NA
1981	660	2134	600		3393		NA
1982	697	2233	738		3668		NA
1983	754	2357	792		3903		NA
1984	778	2051	1261	1109	4090	5199	24829
1985	760	2032	1175	1243	3967	5210	27371
1986	831	1984	1223	2318	4038	6356	29322
1987	756	1985	1433	3156	4174	7330	30464
1988	7[illegible]0	1924	1438	2957	4102	7059	30568
1989	755	1928	1658	2849	4342	7191	29663

[1]The 6.3A category was established in 1974.
[2]SDIO was established in 1984.
[3]Figures were not available for 1970-1983.

4:p. 13] Moreover, many in the S&T community feel SDIO efforts are not sufficiently general to be applicable to the solution of a wide range of military requirements. Instead, it is believed that SDIO efforts are aimed at solving narrowly defined, specific SDI-related requirements. As a result, "when SDI figures are included in DOD's S&T activities, they present a distorted impression of budgetary growth in the S&T programs." [Ref. 31:p. 48] Throughout the remainder of this discussion, references to technology base funding will not include that portion used to fund the SDI program.

Basic research funding has been inconsistent over the last 20 years. Research (6.1) spending declined from $779 million in 1970 and did not return to that level until 1986. Moreover, since 1986, funding has declined 9 percent in constant dollars.

Similarly, support for exploratory development declined throughout the 1970's from its 1970 level. It then rebounded, nearly returning to its 1970 level in 1983. However, between 1983 and 1989, exploratory development funding plummeted once again--about 18 percent in constant dollars.

The budget category, advanced exploratory development (6.3A), was created in 1974. Since that time, budgetary support for this category has almost tripled. Since 1983, all growth in DOD's technology base (excluding SDI) has

occurred in the advanced exploratory development program as indicated in Table 6.

Table 7 highlights the growth of the technology base funding since the establishment of SDIO in 1984. During this period, research (6.1) and exploratory development (6.2) declined 3 percent and 6 percent, respectively, while overall funding for RDT&E experienced 19 percent growth. During this same period, advanced exploratory development without SDI grew only 12 percent while funding for SDI increased 157 percent. As a result, many contend that the S&T program suffered significantly at the expense of SDI. [Ref. 31:p. 56]

DOD faces a period that most believe will be characterized by declining budgets. In this environment, the technology base is particularly vulnerable for two reasons. One is that more immediate procurement concerns tend to take priority, and the other is that technology base programs tend to have a faster spend-out rate than procurement programs. These are explained further in the following paragraphs.

During periods of budget contraction, the services often shift funds from their S&T programs to support more immediate procurement requirements. This was recently demonstrated when the Army cut its research (6.1) funding by almost one-third and cancelled its In-House Laboratory Independent Research program. Table 8 illustrates that the Army, like the other services, supported increases in its research program since FY80. However, when faced with budget

TABLE 7. DOD TECHNOLOGY BASE FUNDING, FY 1984-1989 (millions of 1982$)

	1984	1985	1986	1987	1988	1989	% Change 1984-1989
Basic Research (6.1)	778	760	831	756	740	755	-3
Exploratory Development (6.2)	2051	2032	1984	1985	1924	1928	-6
Advance Exploratory Development without SDI	1261	1175	1223	1433	1438	1408	12
SDIO	1109	1243	2318	3156	2957	2849	157
Total with SDI	5199	5210	6356	7330	7059	7191	38
Total without SDI	4090	3967	4038	4174	4102	4342	6
Total RDT&E	24829	27371	29322	30464	30568	29663	19

TABLE 8. INDIVIDUAL SERVICE FUNDING FOR RESEARCH (6.1)

Year	Army	Navy	Air Force
1980	130.7	214.9	119.2
1981	144.4	241.4	126.6
1982	179.2	276.5	147.4
1983	206.2	307.6	166.4
1984	216.5	320.6	191.4
1985	231.5	341.2	201.3
1986	250.3	342.3	210.2
1987	219.5	354.3	223.3
1988	168.9	342.1	197.7
1989	172.7	355.3	196.4

Source: Office of the Secretary of Defense

constraints in FY87, the Army slashed its research program 12 percent; and in FY88 it reduced its research another 13 percent and eliminated its entire ILIR program.

> ...the connection between today's specific research projects and future military products and technologies is not obvious, cannot be quantified, and is extremely difficult to render in explicit terms. As a result, while everyone agrees that research is important, it is difficult to make an argument that research funding should be supplemented in any given appropriation. [Ref. 4:p. 35]

Conversely, it is far easier to grasp the implications of cutting funds for hardware. A $100 million reduction in procurement funds results in a visible and immediate reduction in the number of tanks or aircraft that can be procured. This has led some to conclude that "while almost everyone would advocate increased R&D funding in the abstract, few are willing to trade more tangible programs for

the vagaries of indefinite technological advances in the future." [Ref. 4:p. 36]

The payout ratio for R&D appropriations is much faster than those for procurement activities. When Congress appropriates funds, the funds are available for disbursement for varying periods depending on the type of activity being funded. Technology base appropriations are generally available for disbursement for a period of two years and about 50 percent of the appropriation is usually disbursed in the first year - hence a 50 percent payout ratio. Alternatively, major procurement items are usually fully funded, which means that appropriated funds are available for disbursement as long as is necessary to build or develop the item. For example, a $3 billion aircraft carrier takes ten or more years to build. Once funds are appropriated for the carrier, they are available for disbursement until the carrier is completed and transferred to the Navy. However, only a very small percentage of the appropriated funds are disbursed in the first year ($150 million, for example). When Congress, DOD and the services calculate budgets and deficits, they are interested in disbursements, or outlays, and not in appropriations. Therefore, in this example, DOD could realize a $150 million saving by reducing the technology base appropriation by $300 million or by eliminating plans for a carrier. [Ref. 4:p. 36]

The Working Group on Technology contends that the trends of declining technology base funding must be reversed. It believes that funding must not only be increased, but it also needs to be stable. Future savings in defense spending must not come at the expense of the technology base effort. [Ref. 1:pp. 30-31]

The Working Group believes that funding must be increased at the expense of force structure if necessary. It further recommends that science and technology funding should grow at a faster rate than the rate of total RDT&E funding. Should RDT&E actually decline, it recommends that S&T should still grow at a 5 percent pace. In either case, it recommends that S&T funding should grow until it comprises 17 percent of RDT&E or $7 billion FY89 dollars, whichever is larger.

Within the technology base, the Working Group recommends the following allocations, where the larger of the two suggested ceilings should govern. Funding for research (6.1) should grow to $1 billion FY89 dollars or 3 percent of the RDT&E budget, and exploratory development should increase to $3 billion FY89 dollars or 7 percent of the RDT&E budget. Advanced exploratory development (6.3A) should also be increased to the same levels as those for exploratory development (6.2). [Ref. 1:pp. 48-49]

B. RISK AVERSE MANAGEMENT PHILOSOPHY

There are two reasons for the risk averse philosophy that pervades DOD's technology base management. The first is that the services are unwilling to undertake programs that do not comply with their own view of their mission or doctrine. The second is that the current philosophy minimizes the risk of failure of any type. Each of these is discussed below.

The services have, on occasion, been unwilling to support technological opportunities that did not coincide with their traditional warfighting missions. Furthermore, "they are in a position to discourage such initiatives." [Ref. 6:p. 24]

> The services are extremely reluctant to support "orphan" functions that are not central to a service's own definition or fighting doctrine. This can present great difficulties for setting well-balanced science and technology priorities, since modern technology has provided capabilities that may not coincide with traditional approaches to mission accomplishment or the accepted division of mission responsibility. [Ref. 6:p. 24]

As an example, the Army's fiber optic guided missile program met with considerable opposition. The missile is capable of hunting and engaging the enemy without exposing the soldier to direct fire. Despite the advantage of providing the soldier in the field with increased survivability and lethality, it was resisted because it conflicted with the Army's traditional "line of sight" combat doctrine. [Ref. 6:p. 25]

The Unmanned Airborne Vehicle (UAV) is a program the Air Force has been reluctant to support. It is known that the

UAV can be an inexpensive platform for a variety of missions, including surveillance, electronic warfare, target acquisition, and weapon engagement. Yet, the Air Force culture prefers piloted aircraft. Consequently, this country's development of UAV's continues to lag. [Ref. 6:p. 25]

A final example is naval mine/countermine warfare. Many experts contend mines could be an effective way of preventing the Soviet fleet from departing the narrow passages from the Black and Baltic Seas. Until recently, the Navy has not afforded mine warfare a very high priority within the technology base. This reluctance led a member of the Defense Science Board to argue that

> ...the Navy has been ignoring mine warfare because "No one can command a mine. You don't get promoted for procuring them, there's no glamour to them." [Ref. 6:p. 25]

The Working Group on Technology views this situation a little differently. It contends that management focuses on research and development programs to meet current operational requirements instead of anticipating future operational problems and new operational concepts. [Ref. 1:p. 23]

The Working Group developed the conceptual device in Figure 5 to illustrate their perception of the current management philosophy with regard to technological innovation and new operational concepts. In Figure 5, both operational concepts and systems technology are divided into "current" and "new" categories. [Ref. 1:pp. 24-25]

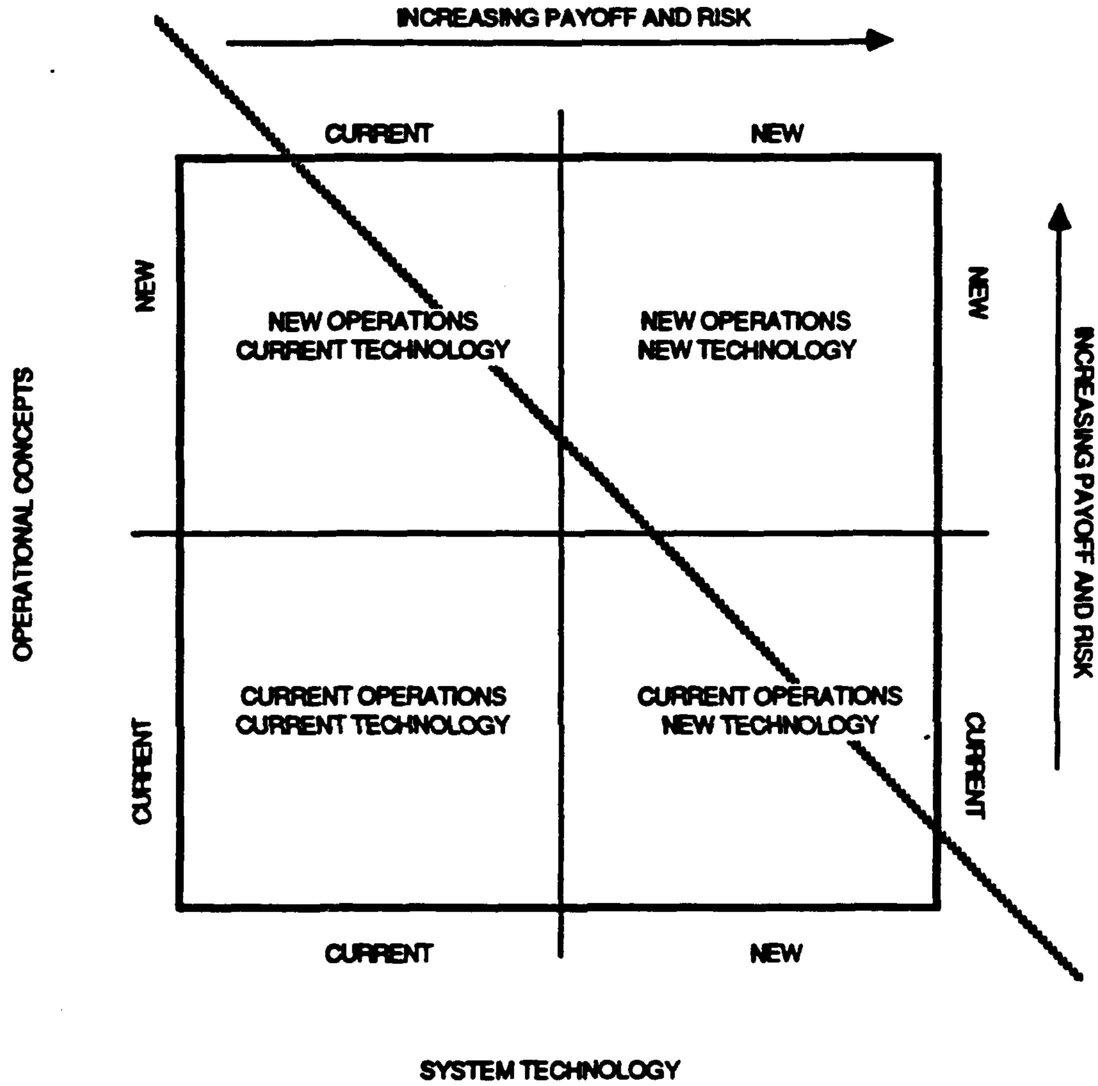

Figure 5. Operational Concepts and Systems/Technology

The Working Group contends that most research and development efforts occur in the lower left hand quadrant of Figure 5 - current technology and current operations. It states that

> ...most DOD development organizations tend to avoid risk and, therefore, their RDT&E activities concentrate on conservative projects that are the most likely to succeed in the sense of meeting cost, schedule, and performance specifications. They tend to operate in the area below the dotted line in Figure 5. [Ref. 1:p. 26]

The Group believes DOD should concentrate greater efforts in the area above the dotted line in Figure 5, where new operational concepts are integrated with new technology. This area offers the highest payoff, but there is also a higher risk of incurring failures in this region. [Ref. 1:p. 25]

The Working Group on Technology also asserts that

> True innovation by its very nature, comes about after repeated attempts and failures: however, current defense management philosophy increasingly emphasizes an intolerance of any failure. In turn, this risk averse orientation provides a powerful and pervasive disincentive to innovation. [Ref. 1:p. 23]

This "failure avoidance" philosophy manifests itself in the disproportionate concentration of technology base efforts designed to solve near-term needs. "It is easier to gain support for research activities that can be related to a current specific military need." [Ref. 6:p. 48] An internal OSD evaluation even concluded that many of DOD's research (6.1) activities were "too well connected to current military needs." [Ref. 1:p. 48]

Short-term research tends to be less risky because it tends to emphasize relatively mature technology with the intent of making incremental, evolutionary advances. Long-term projects are fraught with unknown and unpredictable obstacles.

In summary,

> ...the philosophy of innovation must be injected again in the entire acquisition process. Participants in the acquisition process must be made aware that a premium is being placed on innovative results. Failures arising from ambitious goals are to be not only tolerated in research and exploratory development, but also expected, because repeated tries are a natural part of innovation. The reward structures in the R&D and system acquisition processes needs to be consonant with the premium placed on innovative results. To attract the best talent, provisions must be made for appropriate incentives, both for the individuals and organization that participate in the process. [Ref. 1:pp. 31-32]

C. REQUIREMENTS PULL VERSUS *TECHNOLOGY* PUSH

There is concern that "requirements pull" and "technology push" may be out of balance. Some argue that requirements to prove relevance to military applications may be stifling creativity. Others contend that "excessive loosening of ties between research projects and military needs could lead to a technology base program that produces little practical benefit [Ref. 4:p. 11] This concern is addressed in the following paragraphs.

First, is the question of how to best balance "technology push" against "requirements pull." "Requirements pull" refers to the process of organizing research programs such that they are responsive to the user and the situation he

will face on the battlefield. For example, if a battlefield requirement dictates firepower with a designated range and accuracy, technologies can be pursued to achieve that purpose.

Advocates of "requirements pull" often cite the success of NASA's Apollo Program. The President specified the goal of putting a man on the moon within the decade, and technologies were focused to achieve that objective. Opponents of this approach contend that this achievement did not come cheaply. Resources were diverted from other generic research efforts, the results and benefits of which will never be known. Opponents also cite SDI as an example. It is still not clear whether SDI's objectives can be achieved, but we have spent billions of research dollars pursuing them. "Critics contend that requirements pull and relevance tests dominate the planning process within the DOD science and technology programs." [Ref. 4:p. 31] They believe that "technology push" is more likely to provide quantum leaps in technology, capable of changing the nature of warfare and the way we think about it. They cite technological accomplishments such as nuclear weapons and satellites. These capabilities were not generated in response to specific battlefield requirements. Instead, these dramatic breakthroughs occurred by following new research ideas and opportunities to their logical and technological limits. High-energy lasers and railguns are SDI technologies that

have been pursued because the physics and principles of the proposed technology are understood. [Ref. 4:p. 32]

The task is to determine the best mix of both approaches. Specific threats must be met, but new technological opportunities must also be fully realized.

D. SUMMARY

It is imperative that the technology base is funded at adequate levels. Furthermore, long-range planning must emphasize stability in this funding. The technology base, especially, 6.1 and 6.2, are inherently long-term in nature and if this effort is to yield significant results it must receive stable long-term funding.

DOD and the services must also emphasize and reward innovation. However, this innovation needs to be encouraged within the warfighting communities as well as in the scientific community. Our greatest advances in warfare technology will almost certainly result from the synergism of new technology coupled with innovative concepts for its implementation.

Lastly, there must be increased dialogue between those responsible for research and the warfighters. Informative exchanges will result in technology base priorities which more closely approach an optimum balance between warfighting requirements and research opportunities.

V. RECOMMENDATIONS

The Army's technology base is extremely large and complex. It would be very naive to believe that there are simple solutions to the complex array of problems and issues involved with it. There are no absolute answers. However, the technology base organization and its mechanisms could be modified to improve the efficiency of the process by which technology base decisions are made. The following modifications are recommended:

- Consolidate technology base management and oversight activities in one office.
- Expand the In-House Laboratory Independent Research Program to include provisions for 6.2 activities.
- Establish long-term funding floors for the technology base and each of its components (6.1, 6.2, and 6.3A).
- Continue and expand use of technology gaming for the purpose of formulating long-term investment priorities.

A. CONSOLIDATION

Currently, the Army's technology base efforts are managed and overseen by four major subcommands - the Army Material Command, the Surgeon General of the Army, the Army Corps of Engineers and the Deputy Chief of Staff for Personnel. There are two major disadvantages to the decentralized management arrangement. They are explained in the following paragraphs.

First, the major subcommands that manage the technology base programs are heavily influenced by the clients they

serve. For instance, TRADOC is a key player in the Concepts Based Requirements System which determines AMC's technology research priorities. There is no doubt that the system should be responsive to the user's need. However, there is a possibility that this influence results in an overemphasis on near-term evolutionary technology efforts to satisfy current mission deficiencies.

The second disadvantage is that this decentralization results in a lack of strong high-level support within the Department of the Army. Because responsibility for management and oversight is delegated to four subcommands, the influence of these managers is diluted. The Army would realize stronger and more effective technology base advocacy if it consolidated its management activities in an organization analogous to the Navy's Office of the Chief of Naval Research.

AMC's Technology Planning and Management Directorate (TPM) possesses the skills and personnel to fulfill this role. This organization is such that it already performs many of these duties. Further, the personnel that currently manage and oversee the other three subcommands could augment TPM. TPM should also be elevated organizationally to the Department of the Army level and report directly to the Deputy for Technology and Assessment. This would greatly enhance the technology base program stature and would give

its decision makers enhanced influence within the Army. This would be especially useful for defending technology base activities during budget cuts.

B. EXPANDED ILIR PROGRAM

The Assistant Secretary of the Army for Research Development and Acquisition has directed that In-House Laboratory Independent Research (ILIR) program will account for 10 percent of all 6.1 funds by 1994. This goal should be achieved because this program fosters timely innovation, encourages performance, and allows laboratory directors additional flexibility.

It encourages timely innovation because ILIR projects do not require prior approval and, therefore, bypass the normal Army budget allocation process. It also provides an incentive for enhanced performance because ILIR projects, though not pre-approved, are reviewed annually. Laboratories are awarded additional ILIR funds largely on the basis of this review. Thus, laboratories have a powerful incentive to use ILIR funds wisely. Lastly, the existence of ILIR funds gives laboratory directors flexibility they would not have otherwise. The only restriction on these funds is that they be used for research (6.1) activities. Due to the way in which the funds are awarded, there is little likelihood that this discretion will result in wasteful pursuits.

This study recommends that the Army establish a similar program to support 6.2 activities in much the same way that Navy's Independent Exploratory Development program does. The benefits of the ILIR program - innovation, enhanced performance, and flexibility - should be maximized. It is recommended that a fixed portion of the 6.2 appropriation be designated for this use, as in the 6.1 ILIR program.

C. STABLE LONG-TERM FUNDING FLOORS

It is vitally important to the Army that it establish long-term technology base funding floors - a funding limit which establishes the lowest acceptable level. The Department of Defense, particularly the Army, is entering a period that will most likely be characterized by budgetary retrenchment. The Army will experience troop cuts and procurement programs will be terminated. The leadership of those divisions within the Army suffering reductions will look elsewhere for funds. In 1987 and 1988, when they faced a similar predicament, they turned to the 6.1 program. This cannot be allowed to recur.

Technology base activities, especially research and exploratory development, are activities that require consistent long-term support if they are to be successful. Cyclical funding patterns are detrimental to success. Moreover, the cyclical history of technology base funding is

not one that fluctuates between feast and famine, but rather one that ranges from marginally adequate to inadequate.

There is no obvious answer as to what these floors should be. The Working Group on Technology had some specific ideas for DOD, but these are not necessarily appropriate for the Army. It is important that the Army consider the issue and establish what it believes are adequate funding level targets. During prosperous periods, this target may be increased. However, funding should not be permitted to fall below this pre-established level. This consistency will greatly enhance the success of those responsible for planning the Army's technology base programs and priorities. It is much easier to conduct long-term planning when an accurate assessment of future resources is available.

D. INCREASED WARGAMING

One of the major obstacles to the introduction of breakthrough warfighting technologies is the inability to envision warfighting technologies outside of traditional mission roles. Most groups develop "cultures," and they identify with concepts that fall within the realm of those cultural self-images. They reject those that do not. For example, the infantry was reluctant to accept the FOG-M because it was not a "line-of-sight" weapon.

Technology gaming provides an opportunity for both researchers and soldiers to escape these traditional mindsets

and think more openly about future warfighting opportunities and requirements. Combining both researchers and warfighters in these exercises has synergistic effects. The scientists are able to develop a better idea of what the soldier of the future will require and the soldiers are made aware of the wide range of technology capabilities that may be available. Both groups also develop greater respect and understanding for what the other does and many informal communication channels are opened.

Additionally, the gaming process provides technology base planners with information to make decisions regarding the proper balance between "technology push" and the need to meet current requirements. Concurrently, warfighters gain a greater appreciation for the important mission of the technology base. The gaming process heightens their respect for the facts that past technology base achievements are responsible for current weapons' capabilities and that current research efforts will, inevitably, provide enhanced capabilities in the future.

It is recommended that every effort be made to continue the Army's technology gaming effort. During periods of declining budgets, exercises like technology gaming seem to be the first activities to go. This should not happen. Technology gaming is more important now than ever.

E. SUMMARY

It is unlikely that a methodology will ever be developed to optimize technology base resource allocations. However, these allocations have always been, and always will be, developed by an organizational process which uses certain procedures, or mechanisms, to arrive at allocation decisions. By addressing organizational shortcomings and improving mechanisms, more effective allocation decisions should result. It is hoped that these proposals will promote frank discussion and provoke self examination within the Army's technology base community.

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